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Issued March 11, 1913.

U. S. DEPARTMENT OF AGRICULTURE,
FOREST SERVICE.

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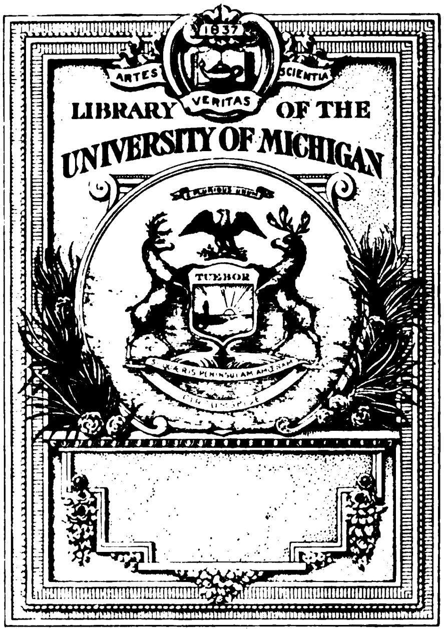
REVIEW
OF
FOREST SERVICE INVESTIGATIONS.

VOLUME I.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1913.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Forest Products Laboratory, Madison, Wis.

Issued March 11, 1913.

U. S. DEPARTMENT OF AGRICULTURE,
FOREST SERVICE.
HENRY S. GRAVES, Forester.

REVIEW
OF
FOREST SERVICE INVESTIGATIONS.

VOLUME I.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1913.

FOREST SERVICE.

Henry S. Graves, *Forester.*
Albert F. Potter, *Associate Forester.*
Herbert A. Smith, *Editor.*

Central Investigative Committee.

Raphael Zon, *Chief of Silvics, Chairman.*
J. T. Jardine, *Inspector of Grazing.*
Carlile P. Winslow, *Engineer in Forest Products.*

District Investigative Committees.

District 1:
  D. T. Mason, *Assistant District Forester in charge of Silviculture, Chairman.*
  C. H. Adams, *Assistant District Forester in charge of Grazing.*
  P. R. Hicks, *Engineer in Wood Preservation.*
  Elers Koch, *Supervisor Lolo National Forest.*

District 2:
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  J. W. Nelson, *Assistant District Forester in charge of Grazing.*
  Norman de W. Betts, *Engineer in Forest Products.*
  C. M. Granger, *Supervisor Medicine Bow National Forest.*

District 3:
  G. A. Pearson, *Chief of Silvics, Chairman.*
  Hugh G. Calkins, *Supervisor Manzano National Forest.*
  Don P. Johnston, *Supervisor Gila National Forest.*
  Stanton G. Smith, *Supervisor Tusayan National Forest.*

District 4:
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  H. E. Fenn, *Assistant District Forester in charge of Grazing.*
  C. G. Smith, *Supervisor Cache National Forest.*

District 5:
  J. A. Mitchell, *Chief of Silvics, Chairman.*
  C. Stowell Smith, *Assistant District Forester in charge of Products.*
  John H. Hatton, *Assistant District Forester in charge of Grazing.*
  P. G. Redington, *Supervisor Sierra National Forest.*

District 6:
  T. T. Munger, *Chief of Silvics, Chairman.*
  H. B. Oakleaf, *Forest Assistant in Products.*
  T. P. MacKenzie, *Assistant District Forester in charge of Grazing.*
  M. L. Merritt, *Deputy Forest Supervisor in charge of Reconnaissance.*

LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Forest Service,
Washington, D. C., October 11, 1912.

Sir: I have the honor to transmit herewith a manuscript entitled "Review of Forest Service Investigations," Volume I, and to recommend its publication.

Full development of the National Forests as productive resources involves extensive research work. Technical forestry is a branch of scientific agriculture and can be successfully applied only as practice is based on accurate knowledge. From the wide range of conditions which the National Forests present, the Forest Service has found it necessary to adopt a comprehensive plan of studies for the systematic investigation of many problems.

As these studies progress it is important that there should be some means of keeping the entire technical force informed concerning the results obtained, of providing for free discussion of methods and tentative conclusions, and of making possible such immediate modifications of existing practice as the discoveries made may warrant. The Review of Forest Service Investigations has been planned to meet this end. Successive numbers will be issued as the material accumulated permits. The Review will contain progress reports on uncompleted investigations and final reports on minor experiments which do not justify separate publication.

It will follow necessarily from the purpose which the Review is designed to serve that a certain freedom will be given for the expression of individual opinion. In other words, the Review will deal largely with matters on which the Forest Service can not yet speak authoritatively; the views presented are for professional consideration, on their merits, and their publication by no means implies that full responsibility for them is assumed by the Forest Service.

While the Review is published primarily for use within the Forest Service, it will unquestionably be valuable also to professional foresters who are not in the employ of the Government and to investigators in closely allied fields of work. A limited provision for public distribution to such persons is therefore recommended. The Review is, however, of professional, not of popular, character.

Respectfully,

Henry S. Graves,
Forester.

Hon. James Wilson,
Secretary of Agriculture.

LABORATORIES AND FOREST EXPERIMENT STATIONS OF THE FOREST SERVICE.

Forest Products Laboratory (in cooperation with the University of Wisconsin), Madison, Wis.

Ground Wood Laboratory, Wausau, Wis.

Wood Testing Laboratory (in cooperation with the University of Washington), Seattle, Wash.

Priest River Experiment Station, on the Kaniksu National Forest, Priest River, Idaho.

Cloquet Experiment Station (in cooperation with the University of Minnesota), Cloquet, Minn.

Fremont Experiment Station, on the Pike National Forest, Manitou, Colo.

Wagon Wheel Gap Experiment Station, on the Rio Grande National Forest, Wagon Wheel Gap, Colo.

Fort Valley Experiment Station, on the Coconino National Forest, Flagstaff, Ariz.

Utah Experiment Station, on the Manti National Forest, Ephraim, Utah.

Feather River Experiment Station, on the Plumas National Forest, Quincy, Cal.

Seed Testing Laboratory and Willow Holt Station, Office of Silvics, Arlington Farm, Washington, D. C.

Dendrological Laboratory, Office of Dendrologist, Washington, D. C.

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REVIEW OF FOREST SERVICE INVESTIGATIONS—
Volume I.

OBJECT OF THE PUBLICATION.

The investigative work of the Forest Service has greatly broadened within the last few years. A large and well-equipped laboratory in forest products is now maintained at Madison, Wis., in cooperation with the University of Wisconsin, with supplemental studies in the East and West. Three Forest experiment stations in the central and southern Rockies, one in the Sierras, and one in northwestern Idaho have been established on National Forests for intensive study of silvicultural problems. In addition one experiment station is being maintained at Cloquet, Minn., in cooperation with the University of Minnesota. Aside from these stations an enormous amount of investigative work has been inaugurated in reforestation, growth, yield, various methods of cutting, and other fundamental aspects of silviculture in every part of the country. An office of grazing studies has been established. Its work, already begun at a grazing experiment station in Utah and on several Forests, is being rapidly extended.

The growth of the scientific work of the Service is a natural response to increasing demand for thorough scientific facts upon which to base the proper handling of the forest and range. The development of the science of forestry and its application to the management of the forest must go on simultaneously. But meager data are available in this country upon which to base scientific forest management and utilization, as the practice and science of forestry developed in the older countries are of little direct value because of differences in species and in climatic and economic conditions. It is very important, therefore, that the results of investigative work be made known, as soon as they are obtained, to the practicing forester, timber owner and user, and to the profession as a whole. The results of the more important investigations of the Forest Service are sooner or later issued as separate publications and become generally available. The completion of many investigations, however, often requires several years, during which very little is known of their progress. The results of minor investigations and observations, which in themselves are not of broad enough scope or sufficiently conclusive to warrant separate publications, yet in the aggregate are of inestimable value, are frequently lost to foresters outside the locality where they were secured.

To provide a means for making the results of such investigations systematically available, as well as the progress attained in the major investigations, a series of publications, to be known as the "Review of Forest Service Investigations," has been undertaken. The object of these publications, of which this is the first, is to give periodically a comprehensive review of the character and progress primarily of the investigative work of the Forest Service, and to some extent also of the various States and forest schools. It will aim to keep all of the men engaged upon investigative work in touch with each other. It will give them the fresh results of each study as it develops. It will be primarily for the interest and benefit of all the investigators in the Service, in all lines of its work, as a cumulative medium for interchange of scientific data and ideas. It is designed to improve investigative methods, avoid duplication, and stimulate interest in research work.

The Review of Forest Service Investigations is issued at intervals as sufficient material accumulates. It is designed to furnish periodically a resumé of the character and progress of the investigative work conducted by the Forest Service. Each issue will contain brief accounts of the progress made on the more important studies whose completion may require several years, and more detailed reports of minor projects whose publication in separate form is inadvisable. Similar material furnished by State foresters will be published from time to time.

It is the purpose of this Review to keep all of the men engaged upon investigative work in touch with each other. The fresh result of each study as it develops will be reported, and a medium furnished for the interchange of scientific data and ideas.

The Review deals largely with matters on which the Forest Service can not yet speak authoritatively and the publication of the views presented does not imply that the Forest Service assumes full responsibility for them.

ORGANIZATION AND SCOPE OF INVESTIGATIVE WORK.

The broad scope of the investigations now carried on by the Forest Service called for an organization which would unify the various scientific activities, prevent duplication, coordinate and correlate all studies, and consider carefully all plans to make sure that the most important problems are attacked in the right way and that all the available information and facilities of the Service are utilized. Such an organization was put into effect in January, 1912, in the form of district and central investigative committees. The creation of these committees marks a progressive step in the development of the investigative work of the Service. It is a recognition of the old principle that several heads are better than one in perfecting plans which call for the best the Service has in scientific attainments and experience in research.

The plan adopted and at present in effect is in general as follows:

In each of the districts, into which the territory occupied by the National Forests is divided, there is a district investigative committee, consisting usually of one representative of each of the major lines of investigation conducted in the district and one supervisor of technical training. Aside from the supervisor the members of the district committees, as far as practicable, are men engaged primarily upon investigative work.

On or before December 15 of each year each district office chief submits to the district committee an annual program of investigative work, under the direction of his office, this program covering:

1. Projects completed during the past calendar year.
2. Program for ensuing calendar year, consisting of (*a*) Incomplete projects upon which work will be continued; (*b*) New projects proposed.

The programs of work submitted by the respective officers are then reviewed by the district committee, special consideration being given to (1) the value of each project under way or proposed; (2) the scope of each project and whether it should be limited or extended; and (3) possible correlation with lines of investigative work in progress or proposed by other offices.

The district committee then prepares a program of investigative work for the district with recommendations regarding the policy to be followed. This program is then carefully considered by the district forester and office chiefs in consultation with the committee. The annual program of work for the district in final form is approved by the district forester. Copies of this program are then submitted to the Forester as a part of the annual investigative report for the district.

The complete programs submitted by the districts are referred to the branch chiefs of the Forest Service in Washington who review and correlate all the work proposed under the direction of each branch. Each branch chief then submits a complete program of work for his branch to the central investigative committee, which consists of three members representing respectively the branches of Silviculture, Products, and Grazing. The branch programs are reviewed by the central investigative committee, which prepares an annual program of work and outlines the investigative policy for the entire Service. This program is then considered by the Forester in consultation with the branch chiefs and central committee.

information in regard to these new and unfamiliar kinds. Many different species of foreign woods are being sold in this country under the familiar trade names of well-known sorts which makes it necessary, in the interest of wood users, to determine the true identity of such imported material and the source from which it comes. For this reason it became necessary to extend to foreign woods also the study of structure as a means of identification. American capital is now being invested in tropical American timber lands, and there is a growing demand for accurate knowledge regarding the identity, uses, and properties of tropical woods.

GRAZING.

The aim of the grazing investigations is to secure thorough scientific information leading to—

1. The production of the maximum value of forage crop.
2. The utilization of timber areas and areas above timber line by grazing without jeopardizing the chances of reforestation and watershed protection further than is justified by the comparative merits of the resources at stake.
3. Securing the greatest grazing efficiency per unit area in utilizing the forage available for use.

Any increase in the value of the forage crop produced must be brought about by (1) successfully seeding range to cultivated forage plants, seed of which can be obtained at a cost which justifies its use; (2) by so managing the grazing of the range as to secure the natural seeding of the most valuable native forage plants in each locality or by developing these valuable native species under cultivation so that seed can be produced at a cost not prohibitive to distribution on the range. The investigations along these lines fall under three headings:

Artificial reseeding.
Natural reseeding.
Distribution and economic importance of forage plants.

All the investigations carried on for the purpose of deciding what portion of the forage crop can be used without undue injury to forest and watershed fall under the one heading:

Forest protection (grazing).

The investigations for the purpose of securing data which will aid in getting the greatest grazing efficiency out of the forage available for use cover the following field:

Methods of handling stock.
Development of stock-watering places.
Poisonous-plant investigations.

The grazing projects comprise both intensive experimental studies and studies initiated primarily to put the results of intensive studies into application in the actual management of the range. The intensive investigations are concentrated at the Utah Experiment Station on the Manti National Forest and on several Forests where there are the best opportunities for studying the problems most important, at present the Coconino, Shasta, and Payette Forests. Less intensive investigations leading to better control of grazing are necessarily carried on in connection with the administration of the range on a number of Forests where particular problems arise.

ARTIFICIAL RESEEDING.

The aim of studies in artificial reseeding is to determine means of restoring overgrazed areas and improving the quality of the forage by artificial reseeding with cultivated plants. But a comparatively small acreage of National Forest range is adapted to the growth of the forage plants for which seed is available, due to excessive altitude, poor soil, drought, or other conditions. In order to carry on successfully artificial reseeding of the range, it is important to find out (1) the lands where seeding to cultivated species is economically possible as determined by altitude, exposure, soil, moisture, and native vegetation; (2) the species best adapted to any given set of conditions; (3) the time to sow, the cultural methods which should be used; and (4) the necessary protection against grazing. In addition, the most promising native species are being tried under cultivation experimentally to determine the possibility of their use in artificial reseeding.

NATURAL RESEEDING.

Investigations of this character aim to determine the possibilities of naturally reseeding depleted lands that still have a part of the native vegetation, and to devise systems of grazing management which will permit of the regeneration of the lands without a loss of forage values. These investigations are both intensive and extensive. The intensive studies aim to find out the important forage plants, determine their absolute requirements of growth and reproduction, and with these data as a basis, perfect a plan of grazing management which will allow the plants to reseed naturally often enough to keep the range in maximum condition—this with the least possible loss of forage. The extensive studies aim to put the data collected from the intensive studies on a practical basis by demonstration application to range management.

DISTRIBUTION AND ECONOMIC IMPORTANCE OF FORAGE PLANTS.

The aim of this work is to ascertain the species of plants which make up the forage crop as well as the objectionable and worthless plants on each Forest range, and to determine the forage value, growth requirements, seasons of growth, time of seed maturity, and class of stock for which each is best adapted. With a thorough knowledge on these points regarding the plants which make up the forage crop on each Forest, there will be greater possibility of developing a plan of grazing management which will sufficiently recognize the growth requirements of the vegetation to maintain a maximum yield without unnecessary loss of forage by nonuse.

FOREST PROTECTION (GRAZING).

The aim of studies along this line is to collect information which will result in a decision as to the proper relation of grazing to National Forest management. The work comprises (1) studies to determine the effect, both detrimental and beneficial, of grazing upon tree reproduction and the possibility of eliminating damage or increasing the beneficial effect by changes in grazing management; (2) studies to determine the influence of grazing upon "run-off" and erosion; (3) studies to determine the influence of grazing as a protection against fire. The projects under (1) and (2) must necessarily be intensive and will be carried on at the Utah Experiment Station or on a few selected Forests.

METHODS OF HANDLING STOCK.

Investigations of this character aim at eliminating, so far as practicable, any waste of forage in utilization of the range by reducing to a minimum the loss of forage due to trampling and by reducing the damage that comes from interfering with natural processes of revegetation and damage to tree growth and watersheds. The work covers studies to determine: The most satisfactory number of sheep to be run in one band, considering the welfare of the range and the sheep and the interests of the sheep owner; the best method of herding or handling, salting, bedding, and watering the sheep; methods of handling cattle, and other grazing animals (swine, horses, goats).

DEVELOPMENT OF STOCK-WATERING PLACES.

Without an adequate distribution of water for the stock on the range, it is frequently impracticable to adopt a system of grazing management which will place on a range the class of stock to which it is best adapted at the time when it should be utilized, and to plan the handling of the stock so as to secure complete utilization without waste of forage. The studies along this line aim to secure information upon which to base a decision as to the necessary distribution and capacity of watering places under a given set of topographic, climatic, and forage conditions; and how best to develop watering places from different sources of water supply.

POISONOUS PLANT INVESTIGATIONS.

The scientific data on poisonous plants are very largely collected by the Bureau of Plant Industry. The Forest Service is cooperating in working out the abundance, distribution, and seasons of growth in various localities of the species of plants poisonous to stock.

PRODUCTS.

The aim of the investigations conducted by Products is to secure authentic information regarding the properties and suitability for different purposes of various species and kinds of forest products. Such information is essential to increase the efficiency of the methods at present in use in the production and utilization of forest products, and is necessary for the most economical management of the National Forests.

In accordance with the general policy of centralizing the investigative work at specific points, practically all of the products studies are conducted at a few definite stations. The Forest Products Laboratory at Madison, Wis., is the headquarters at which is conducted the great bulk of the work. This laboratory, which is maintained in cooperation with the University of Wisconsin, is well equipped for conducting most of the lines of work discussed later. Laboratories are also maintained at Wausau, Wis., where the groundwood pulp investigations are all conducted, and at Seattle, Wash., where certain tests on the mechanical properties of woods are carried on. District stations are also permanently established at Washington, D. C., San Francisco, Cal., and Portland, Oreg., and certain more general investigations are conducted from these points.

The investigative work falls into four major divisions, with a number of subdivisions, as follows:

- A. Mechanical and Physical Properties and Structure of Woods.
  - Mechanical properties.
    - Tests on small specimens free from defects.
    - Tests on structural timbers.
    - Tests on manufactured articles.
    - Effect of preservative treatment, moisture, etc.
  - Physical properties.
    - Fundamental properties.
    - Conditioning experiments.
    - General.
  - Relation of structure to properties.
- B. Wood Preservation.
  - Preservatives.
    - General.
    - Physical and chemical properties.
    - Toxicity.
    - Effect on strength of wood.
    - Inflammability.
    - Ease of injection into wood.

B. Wood Preservation—Continued.
  Processes.
    Commercially established.
    New or proposed.
    Effect of varying conditions during treatment.
  Suitability of species.
    Resistance to impregnation with preservatives.
    Resistance to decay.
    Preparation for treatment.
  Cooperative field work and service tests.
C. Derived Products.
  Pulp and paper.
    Mechanical or grinding processes.
    Chemical processes.
  Wood distillation.
    Hardwoods.
    Resinous woods.
  Naval stores, or turpentine and rosin.
  Miscellaneous.
    Production of ethyl alcohol.
    Production of tannins.
    Production of gas from wood waste.
    Production of essential oils from leaves, twigs, etc.
    Chemical composition of various woods.
D. Statistical Studies.
  Annual production of forest products.
  Study of uses of woods (by States, industries, and species).
  Lumber prices.
  Miscellaneous.

MECHANICAL PROPERTIES OF WOOD.

These tests are primarily for the purpose of accumulating reliable information on the mechanical properties of various species and forms of timber. The results are of value to all engineers, manufacturers, and other users of wood in enabling them to employ the various species and forms most advantageously, and frequently to substitute less well-known species for those which have been commonly used but are now becoming scarce. The nature of the investigations is such that they may be classified under the following headings:

TESTS ON SMALL SPECIMENS FREE FROM DEFECTS.

The purpose and general nature of these investigations are as follows:

(*a*) To establish scales by means of which it will be possible to compare directly the bending strength, compressive strength, shearing, stiffness, toughness, hardness, cleavability, coefficient of shrinkage, and specific gravity or dry weight of the commercial timbers of the United States. Such scales will make it easier for users to select substitutes for species which are becoming scarce.

(*b*) To correlate the properties listed above with the rate of growth, the position of the specimen in the tree, the physical characteristics of the tree, and the locality and conditions under which the tree grew. Such analyses are primarily for the use of a forester if the conditions in this country ever permit the selection of material in the woods with respect to its suitability for certain specific purposes.

TESTS ON STRUCTURAL TIMBERS.

The purpose of these investigations is as follows:

(*a*) To supply engineers and architects with data on which to base moduli for use in the design of structures built of timber.

(*b*) To correlate the results of the tests with the physical characteristics of the timber and with the character and location of defects in order to establish a more correct basis for the grading of large timbers according to their mechanical properties.

(*c*) To establish a relation between results obtained from large timbers containing defects and those obtained from small specimens free from defects, so that the strength of structural timbers may be estimated from tests on small pieces.

TESTS ON MANUFACTURED ARTICLES.

This series includes tests on axles, spokes, cross-arms, poles, and other manufactured articles. They constitute, however, a minor part of the investigative work and are made primarily for the purpose of demonstrating the fitness of a substitute species or a lower grade of material for specific uses.

EFFECT OF PRESERVATIVE TREATMENTS, MOISTURE, ETC.

This series of tests is for the purpose of studying the effect of moisture, preservative treatments, methods of seasoning, fireproofing, etc., upon the mechanical properties of wood. Both structural forms and small specimens free from defects are used in the various studies, the form and character of the specimens in each case being determined by the nature of the problem.

PHYSICAL PROPERTIES OF WOOD.

From the foregoing brief outline of the purpose and scope of the investigations on the mechanical properties it can readily be seen that they are closely connected with similar investigations on the physical properties of wood. The work falls into the following divisions:

FUNDAMENTAL PROPERTIES.

A knowledge of the fundamental physical properties of wood in general and of the various species individually is essential to the most efficient utilization of the material. Not only is such knowledge of prime importance in connection with studies on the structural and mechanical properties, but it is especially necessary for the most successful conducting of investigations relating to wood preservation and some other wood-using industries. The several lines of investigation cover studies of the thermal properties, penetrability to liquids and gases, hygroscopicity, density of wood substance, etc.

CONDITIONING EXPERIMENTS.

These experiments relate primarily to the application of the knowledge of the structure, mechanical properties, and fundamental physical properties of wood in its preparation and handling for commercial uses, and consist largely of investigations into seasoning and drying. The results will be of value to all engaged in the manufacture and utilization of wood products, such as lumber, structural timber, ties, poles, wagons and vehicles, implements, and furniture. In the manufacture and handling of such products much money and time are spent in seasoning the wood, and often a considerable proportion of the raw material is lost or damaged as a result of improper seasoning. Information on the fundamental principles of drying lumber is needed in order to improve these conditions. The investigations logically fall into three divisions, as follows:

(*a*) *Air seasoning.*—The importance of this work is evident when it is considered that it affects the entire lumbering and wood-manufacturing industries. Not only is seasoning essential in the production and utilization of a large proportion of the products, but much material inadvertently becomes seasoned as a result of enforced storage of raw material or finished product. Furthermore, it is necessary in practically all cases to air season material prior to kiln drying by the methods in general commercial use. In spite of the importance of the subject, however, and the well-known advantages of properly seasoned timber, such as increased strength, durability, and penetrability to liquids, much material is annually damaged by checking, decay, sap staining, and other agencies, with a corresponding financial loss.

It is the purpose of the investigations to assist in bettering these conditions by securing data on the proper methods of piling and the time required to air season various forms and species in various localities. The results are of especial value to the Forest Service in the work under way on wood preservation, kiln drying, and mechanical properties of wood.

(*b*) *Kiln drying.*—The time required to air season wood properly is so great that artificial methods of drying are being almost universally applied. Unfortunately, however, methods do not yet permit of wood being kiln dried without first being seasoned at least to a partial extent. The big problem which confronts the users of wood is to

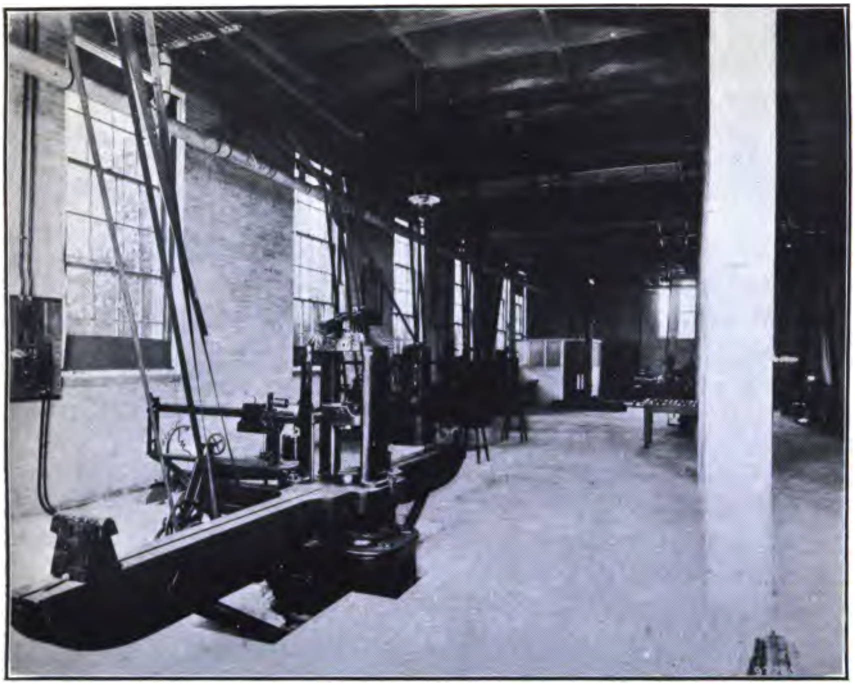


FIG. 1.—MACHINES FOR TESTING THE MECHANICAL PROPERTIES OF WOODS, FOREST PRODUCTS LABORATORY.

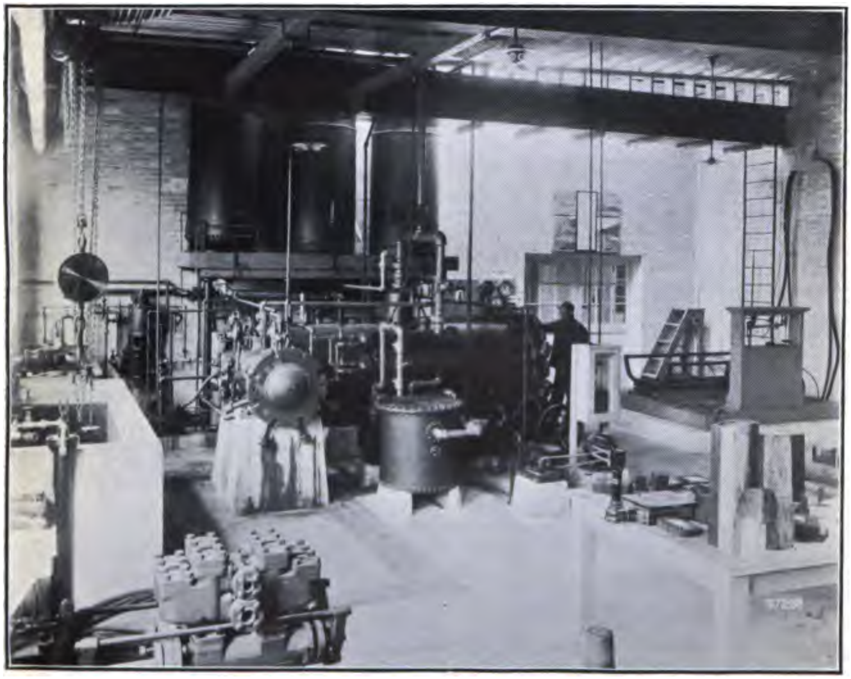


FIG. 2.—EQUIPMENT FOR WOOD PRESERVATION EXPERIMENTS, FOREST PRODUCTS LABORATORY.

season it in the shortest possible time. All methods at present in use are more or less imperfect, and it is conservatively estimated that at least 10 per cent of the material dried in kilns is ruined or greatly lowered in value by excessive checking, warping, honeycombing, etc. To study the fundamental principles of drying in kilns with a view to finding means of overcoming the present difficulties is one of the aims of these investigations.

(*c*) *High temperature and pressure treatments.*—Very little is known concerning the behavior of wood when subjected to high temperatures and pressures or to various conditions of the surrounding medium. Preliminary experiments indicate that certain of the physical and mechanical properties, such as density, strength, hardness, and hygroscopicity, can be altered by such treatments. The aim of these investigations is to find methods of altering the properties of the less valuable woods so as to increase their field of use.

GENERAL STUDIES.

These investigations are so varied in nature that they can not be classified under any specific heading.

RELATION OF STRUCTURE TO PROPERTIES.

These investigations aim to find the effect of different kinds of structure on the mechanical and physical properties of woods and to show the structure best adapted for certain specific uses. The work may lead to several methods of grouping, based on the use intended and independent of the botanical classification. The study of wood elements and fibers as found in pulp forms an important phase of the work, as does also the effect of structure on the penetrance of preservatives.

WOOD PRESERVATION.

These investigations deal with the protection or preservation of wood from destruction by decay, fire, abrasion, and insects. Of these, decay is by far the most important, and it is with this that the investigations are mostly concerned.

The importance of the investigations are illustrated by the fact that over 100,000,000 cubic feet of wood were treated in 1910 with preservatives to protect them from decay, which is an increase of over 500 per cent of that treated during 1904. Although it can be appreciated at once that the industry is rapidly growing and becoming established in this country, there are still many points on which further and more definite information is required in order that the most efficient methods may be employed. The nature of the investigations can best be discussed separately under the following classifications:

PRESERVATIVES.

GENERAL.

The cost of preservatives amounts to from 50 to 90 per cent of the total cost of treatment, and the ultimate success of any treatment is largely dependent upon the preservative used. Many substances have been tried as preservatives, and a variety of opinions exist as to what preservative will give the greatest efficiency under different conditions.

It is the purpose of the work to secure authentic information on the relative efficiency of various preservatives which are now being used commercially or which give promise of success in preventing decay. The work may be classed into investigations of oils, metallic salts, and other materials, their efficiency depending to a greater or less extent upon the following points:

PHYSICAL AND CHEMICAL PROPERTIES.

This is the first step in studying the efficiency of any preservative. It may frequently happen that a determination of these properties is immediately sufficient to prove the product unsatisfactory.

TOXICITY.

The success of many preservatives depends entirely upon their antiseptic or toxic properties, or, in other words, upon their poisonous effect upon decay-producing organisms, insects, or marine borers. This is true of all the metallic salts and in a large measure of many of the other preservatives used.

EFFECT ON STRENGTH OF WOOD.

However efficient a preservative may be in retarding decay, it is evidently essential for the great majority of cases that the strength of wood should not be seriously affected by its injection.

INFLAMMABILITY.

There are many instances where a preservative might be advantageously used were it not for the danger of increasing the inflammability of the timber. This is especially true in such cases as mine timbers, where the wet conditions are frequently adverse to the use of metallic salts and where the use of creosote or other oils would be effective were it not for the possible increased danger from fire. Furthermore, the protection of wood against fire is an important field in the wood-preservation work, since more stringent rules are everywhere being put into effect regarding the use of inflammable material in buildings.

EASE OF INJECTION INTO WOOD.

This is an important aspect in determining the efficiency of a preservative, since it is evident that its efficiency is impaired if it can [illegible] into the wood with comparative ease.

PROCESSES.

Closely related to the work on preservatives is the investigative work on processes. However efficient a preservative may be in itself, it is important that it be injected into the wood in the most efficient and economical manner. The work covers investigations of the relative efficiency of the various processes in commercial use, of proposed or new processes, and of the effect of varying conditions during treatment. The intention is to determine the effect of each step in various established and proposed processes upon the impregnation of the wood and its condition after treatment.

SUITABILITY OF SPECIES.

Closely related to the work on preservatives and processes is the determination of the suitability of various species for treatment. One of the chief aims of such work is to increase the use of the cheaper and less durable woods, of which there is a plentiful supply, in place of the more costly and naturally durable woods which are more generally used. Information on the relative permeability of various woods will be of value to the consumer in selecting his material and of special value to the Forest Service in disposing of many species on the National Forests for which at present there is no great demand. The work involves investigations to determine the resistance of woods to impregnation with preservatives, their relative resistance to decay, and the methods necessary to satisfactorily prepare them for treatment.

COOPERATIVE FIELD WORK AND SERVICE TESTS.

Owing to the comparatively recent development of wood preservation in this country, one portion of the work on this subject consists of cooperative field work and of service tests. The final test of any preservative or process applied to any species or form of material is to place such material under actual conditions of service and note the results.

PRODUCTS DERIVED FROM WOOD, BARK, LEAVES, AND THE GROWING TIMBER.

The investigations on derived products are divided according to the product under consideration, as follows:

PULP AND PAPER.

The manufacture of pulp and paper is a well-established industry which uses wood and rags as raw material and whose products are in large demand. Its magnitude as a wood-using industry is shown by the fact that in 1909 over 4,000,000 cords of wood were consumed. The cost for this wood alone was over $33,000,000. The annual consumption of wood for pulp products increased over 100 per cent from 1900 to 1909, while its cost increased over 240 per cent. Since 60 per cent of the wood used for pulp in 1909 was spruce and 15 per cent hemlock, the importance of investigating the value for pulp of species at present little used and of various forms of wood waste is evident. Studies of methods to increase the efficiency of established processes are also needed.

The pulp investigations may be classified as follows:

MECHANICAL OR GRINDING PROCESSES.

So far as the immediate needs of the paper trade are concerned, this work is of the greatest importance. Much of the cheaper paper, such as news print, is made from pulp produced in this way. At the present time practically the entire supply of ground-wood pulp is produced from spruce, and the diminishing supply and increasing price of this species makes the search for satisfactory substitutes of live interest to pulp manufacturers. A study of the details of the processes used in making different kinds of pulp is also carried on with a view to determining the most efficient methods of production.

CHEMICAL PROCESSES.

It is by chemical processes that pulp for use in the finer and stronger grades of paper is produced, and although a greater variety of woods are used than for the ground-wood pulp the fundamental problem confronting the industry here also is the supply of raw material. In 1909 over 85 per cent of the wood consumed consisted of spruce, hemlock, poplar, and balsam, and it is the prime aim of the investigative work to determine the relative suitability of other available species and forms of material.

In studying the suitability of the various woods, their adaptability for the different established processes must be considered. This involves a thorough knowledge of the various processes and of the effect of varying certain conditions on the final product. The work on species and processes, therefore, is closely connected and may be classified into:

(*a*) Studies with the soda process, which is a well-established process suited for either deciduous or highly resinous woods;

(*b*) Studies with the sulphite process, which is the process now most extensively used in this country and is especially adapted for the not too resinous conifers and for the production of pulps where a very white natural color is desired;

(*c*) Studies with the sulphate process, which, although used only to a limited extent in this country at present, gives promise of becoming of more importance especially for the manufacture of pulps from the southern pines and more resinous woods.

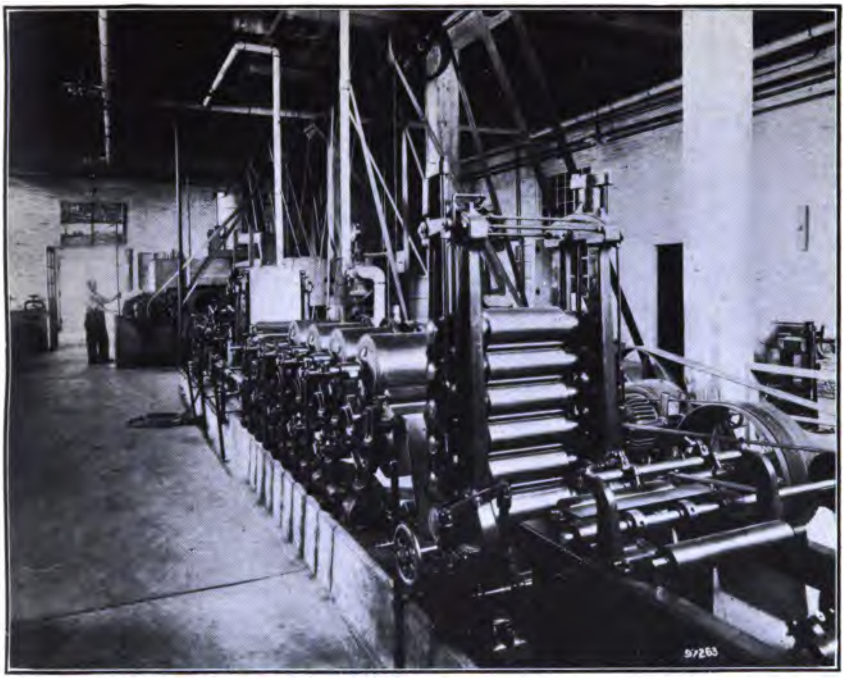


FIG. 1.—PAPER MACHINE, FOREST PRODUCTS LABORATORY.

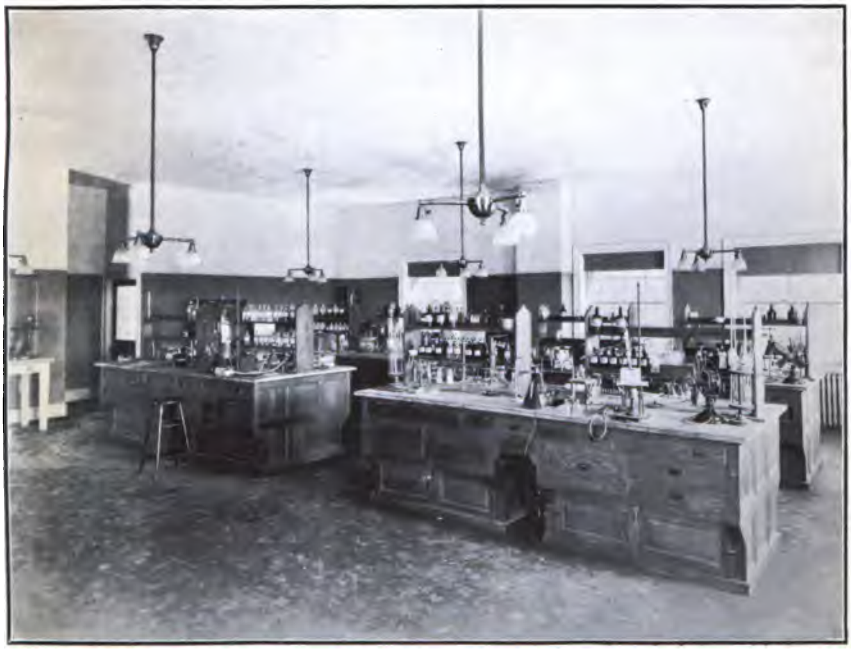


FIG. 2.—EQUIPMENT FOR ANALYZING AND TESTING PRESERVATIVES, TURPENTINE, PRODUCTS OF WOOD DISTILLATION, ETC., FOREST PRODUCTS LABORATORY.

WOOD DISTILLATION.

Wood distillation is already a fairly well-established industry, consisting of two distinct branches—hardwood distillation and resinous wood distillation. Both branches depend on waste wood to a large extent for raw material so that the investigations consist (1) of a study of new species which may be found suitable; (2) of the development of more efficient methods of production and refining; and (3) of the determination of the properties of distillation products not readily marketable at present.

The nature of the two branches of the work is as follows:

HARDWOODS.

This is an established industry with fairly well-standardized processes. Two of the main products—acetate of lime and wood alcohol—are regularly quoted market articles. The third, charcoal, is usually sold to iron furnaces or in other local markets for fuel. In many of the commercial plants wood cut especially for the purpose is used, while others are operated on sawmill waste, so that only that part of the tree not suitable for lumber is used for distillation. Small-sized material, such as sawdust and shavings, is not practicable, since the charcoal produced is so fine that it is difficult to cool and handle, and the small size of the material makes it such a poor conductor of heat that it is impossible to char it satisfactorily in the ordinary forms of apparatus.

The species most extensively used in commercial work are birch, beech, and maple. The amount of valuable products that can be obtained from these woods is comparatively well known, but very little information is available for other species. The purpose of the investigations, therefore, is primarily to determine the suitability of other species for distillation purposes.

RESINOUS WOODS.

This is a comparatively recent industry in this country for which standard methods have not yet been developed. Some of the products also have not yet become standard market articles. The investigations cover the following fields:

(*a*) *Destructive distillation.*—In selecting material for this purpose the governing factor is the amount of resin or pitch present in the wood, and since this resin content is variable for different trees of the same species, and even in different parts of the same tree, it is usually necessary to select the wood in order to obtain a material sufficiently rich for distillation. The largest portion of material at present used consists of "lightwood" from longleaf pine. Stump wood from the same species has been used also to some extent; but the "lightwood" is commonly used, since the stump wood is more difficult to collect and prepare for distillation.

(*b*) *Steam distillation.*—There is another form of material, such as the average run of sawmill waste, sawdust, and slabs from longleaf pine, which on account of its comparatively small resin content can not be used economically for destructive distillation, and apparently the only process which is applicable to this class of material is the simple and more rapid steam-distillation process, which recovers only the volatile oils originally present as such in the wood.

It is the purpose of these investigations (1) to standardize methods of distillation for various species and classes of material and (2) to determine the quality and value of the various products which may be secured.

(*c*) *Extraction methods.*—In the distillation of resinous woods one of the most valuable products—rosin—is not secured. Methods have been developed for securing this product by extraction from the wood with chemicals, and these investigations deal with a study of such methods.

Naval Stores or Turpentine and Rosin.

The naval-stores industry has long been established in this country. The general method of procedure is to tap the resinous longleaf pine trees and collect the gum, which is subsequently distilled and refined into the two major products—turpentine and rosin. Under existing methods of operations there is considerable loss of possible products owing to unscientific methods of tapping the trees and collecting the gum, while at the same time it is believed that other species than longleaf pine might prove of value for this purpose. The study of new species and the refinement of operations is the main purpose of the investigative work.

Miscellaneous.

Work under this heading covers investigations which are not so broad in scope as the foregoing. They deal primarily with the utilization by transformation into other products of waste incident to mill operations and existing in the forests, and also include studies which do not deal primarily with the utilization of waste, but are nevertheless of value in furthering this work. Investigations at present under way deal with the production of ethyl alcohol, tannins, gas, essential oils from leaves and twigs, and the chemical composition of various woods.

STATISTICAL STUDIES.

This work deals with the collection and compilation of statistics on the amounts, prices, sources, and uses of various forest products produced annually and with studies to show where and how the waste occurs and how it may be reduced. The work is of importance (1) to the Forest Service in so far as it assists in determining the lines of work which require investigations, and (2) to the Forest Service and users of wood at large in furnishing information regarding the consumption and utilization of various woods and wooden products in different sections of the country.

The work falls into the following divisions:

ANNUAL PRODUCTION OF FOREST PRODUCTS.

This work deals with the collection of statistics showing the annual production of the major forest products and is of importance in giving a reliable yearly record of the extent and changes in the demand upon the forests for each kind of wood by States.

USES OF WOODS AND THE MANUFACTURE OF WOODEN PRODUCTS.

The purpose of these investigations is to show the annual consumption of wood by the wood-using industries and to determine the conditions governing its use and the processes of manufacture. The part each species plays in wood economics is thus traced from the sawmill to the finished product. The information secured is of special value to the Government and other owners of timber, since it points out the best markets for each kind of wood. It is also of value to the manufacturer in enabling him to determine where he can best buy the material which he requires.

LUMBER PRICES.

The purpose of this work is to secure periodically wholesale prices of lumber both at the mills and principal markets. The information has two main applications:

1. It provides a continuous statistical record of the prices of the various woods in all parts of the country.
2. It determines the part which freight and selling charges play in determining the wholesale price of the different grades.

MISCELLANEOUS.

This covers minor work of a statistical nature, such as the collection of statistics on the quantity of wood preservatives annually consumed and the extent of the substitution of other materials for wood.

SILVICULTURE.

The aim of the silvicultural investigations is to secure a thorough knowledge of the silvical characteristics and requirements of all forest trees, a solid scientific basis for the silvicultural handling of existing forests, and for the establishment of new forests to secure the most economic use of the timber and other products of the forest and a more exact knowledge of its indirect benefits. The silvicultural investigations are necessarily conducted along two distinct lines, as experimental studies and general studies.

The experimental work as now conducted at the Forest experiment stations is by far the most important. For the last few years it has been felt that only by well-ordered experiments can empirical procedure be replaced by truly scientific procedure. The experimental work is carried on chiefly at the seven Forest experiment stations of the Forest Service: the Fremont Station on the Pike National Forest near Pikes Peak in Colorado; the Wagon Wheel Gap Station on the Rio Grande National Forest, also in Colorado; the Fort Valley Station near Flagstaff, Ariz., and its substations; the Priest River Station on the Kaniksu National Forest in Idaho; the Feather River Station on the Plumas National Forest in California; the Utah Station on the Manti National Forest in Utah, and at the Arlington Farm in Washington, D. C., although a large number of experiments are conducted on various Forests and in cooperation with several States on State lands.

General studies which can not be confined to one locality, such as regional or tree studies, are necessarily made where favorable conditions exist for carrying them on.

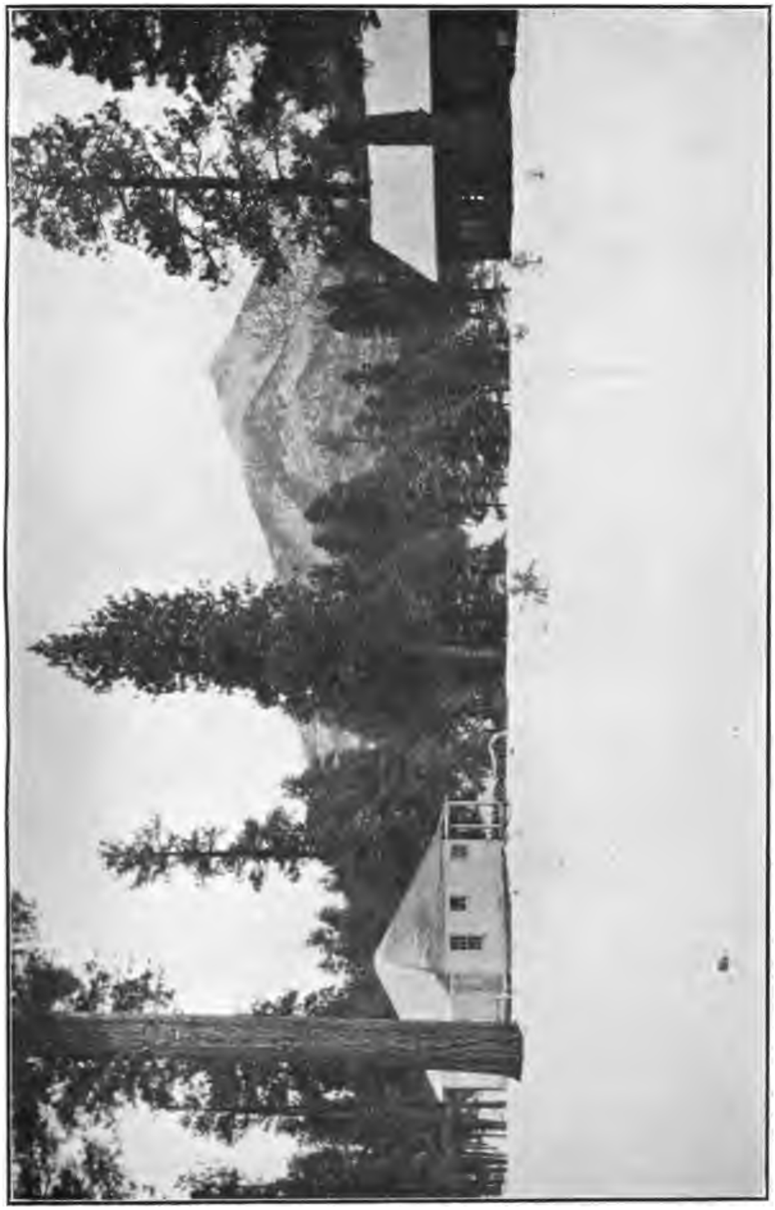
FOREST EXPERIMENT STATIONS.

The Forest experiment stations are the outgrowth of the need for scientific information which can be secured only in a systematic manner and by intensive methods of study. The Forest experiment station idea is not a new one; it has already been developed extensively in several European countries. The value of the systematic organization of Forest research work was officially recognized in Germany in 1870, when the first Forest experiment station was established in Baden, in connection with the Polytechnikum at Carlsruhe. Half a dozen of the German States followed the example, instituting main experiment stations in connection with forest schools, and branches in various forest districts. The cost to the German Government is in the neighborhood of $30,000 annually. The work done is intensely scientific, and the policy of forest experiment stations is steadily growing in favor.

In India, where the work of research has been neglected for a long time, the need for scientific investigation has now been recognized by the Government, and an Imperial Forest Research Institute and College has been created at Dehra Dun, with a faculty chosen from the Imperial Forest Service.

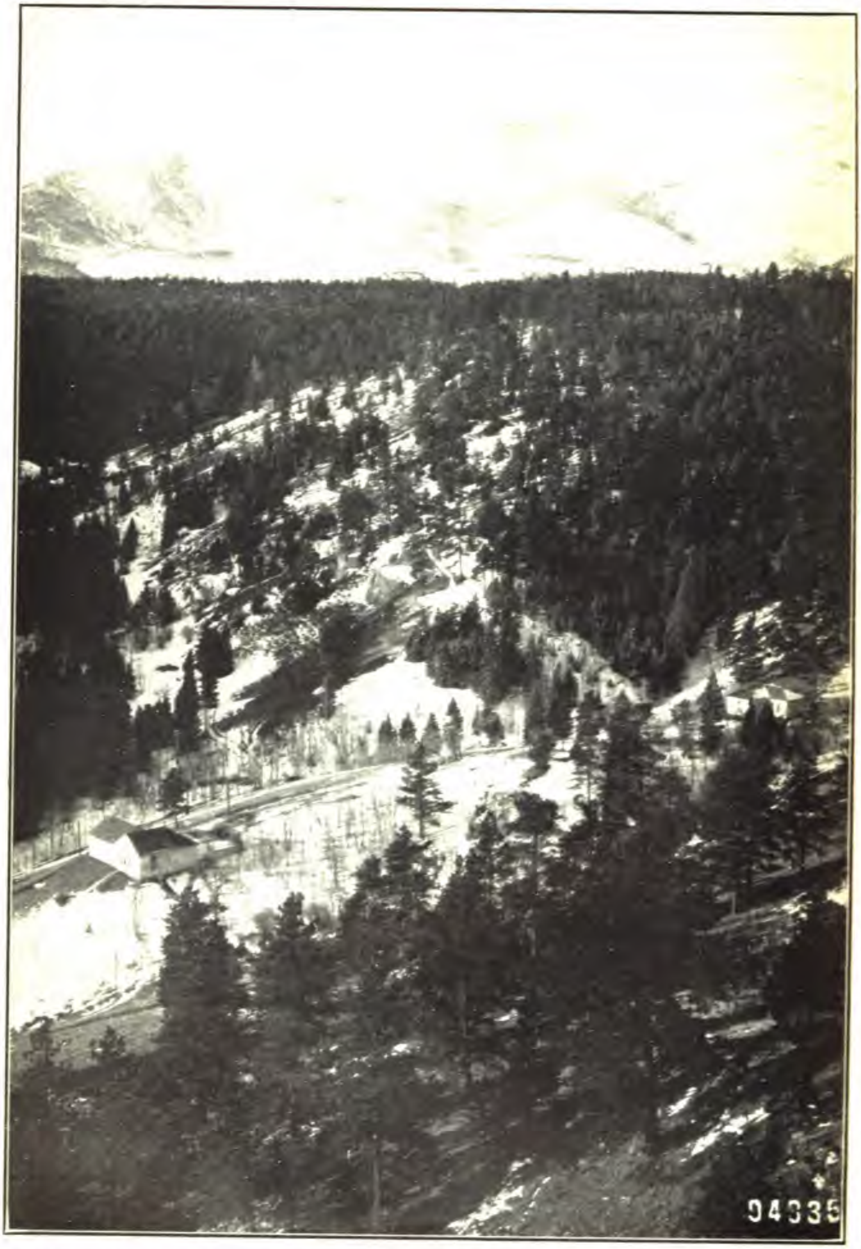
In the United States considerable research work has been done in connection with forest problems. The beginning of real investigative work in silviculture, however, must date from the establishment

PLATE IV.



REAR VIEW OF FORT VALLEY EXPERIMENT STATION GROUNDS, WITH SAN FRANCISCO MOUNTAINS IN THE DISTANCE. TO THE RIGHT, RESIDENCE OF OFFICER IN CHARGE; TO THE LEFT, ASSISTANTS' QUARTERS.

PLATE V.



HEADQUARTERS OF FREMONT EXPERIMENT STATION, PIKES PEAK IN THE BACKGROUND.

of the first experiment station at Flagstaff, Ariz., in the summer of 1908. Advantages of economy and greater efficiency in conducting investigative work in silviculture at an experiment station are apparent. Under the old system of conducting investigative work, assignments to an extensive area were usually necessary, to which the observer could devote but a short field season. Under the system of Forest experiment stations, specially trained men are permanently assigned to a given region with which they have an opportunity to become thoroughly familiar and therefore are capable of conducting the work with the greatest effectiveness and least expense. Each of the experiment stations is allotted an area sufficient for the proper handling of short-period experiments, for experiments requiring a number of years, and for the maintenance of large permanent sample areas which serve as models typical of the silvicultural region. Such areas furnish the most valuable, instructive, and convincing object lessons for the public in general, for professional foresters, lumbermen, and owners of forest land, and especially for the technical and administrative officers of the National Forests.

The organization of the Forest experiment stations made possible the use of uniform methods in dealing with forest problems. General problems are treated at the different stations simultaneously; local problems in the region to which their results apply. All of the modifying factors which enter into the results of experiments are measured by observations covering many conditions and years and are thus determined once for all with the greatest economy and the least duplication of work.

The stations are distributed in such a way that one station is located in each of the silvicultural regions of the West. A single Forest, representing as much as possible the conditions typical of the region, is selected and a portion of this area set aside for the purposes of the experiment station.

FORT VALLEY EXPERIMENT STATION.

This is the oldest station, having been established in the summer of 1908. It is located on the Coconino National Forest within 8 miles of Flagstaff, and is typical of the western yellow-pine forests of the Southwest.

FREMONT EXPERIMENT STATION.

This station was stablished in 1909. It was named in honor of Gen. John C. Fremont, a famous explorer of the Pikes Peak region. It is located on the front range of the Rocky Mountains, 75 miles south of Denver, 10 miles west of Colorado Springs, and 2 miles from Manitou, which is at the base of the mountains. The situation may be said to be on the slope of Pikes Peak, although the station is nearly 4 miles from the Peak and 1 mile lower than its summit. At approximately 8,850 feet elevation, the Fremont Station is almost at the middle of the forest range, timber line on the Peak being at 11,500 feet, and the lower limit of forest growth at about 6,500. Either extreme of tree growth is within 4 miles of the station. The Pike National Forest is an especially desirable site for a Forest experiment station on account of the wide range of altitude which it covers and the versatility of physical conditions within its limits. The forest types surrounding the station are those of western yellow pine, Douglas fir, and Engelmann spruce.

WAGON WHEEL GAP EXPERIMENT STATION.

This station was established in 1910. While it is almost in the same region as the Fremont Experiment Station, the purpose for which it was organized is entirely distinct, namely, the study of the effect of forest cover upon streamflow. It is located on the Rio Grande National Forest near Wagon Wheel Gap, and the watershed studies are carried on in cooperation with the United States Weather Bureau.

PRIEST RIVER EXPERIMENT STATION.

This station was organized in the fall of 1911. It is located on the Kaniksu National Forest about 14 miles from the town of Priest River. It is typical of the limited silvicultural region composed of western white pine and western larch.

FEATHER RIVER EXPERIMENT STATION.

This station was organized in the fall of 1912. It is located on the Plumas National Forest on the west side of the Sierras. It is within a region typical of the western slope of the Sierras where the most important species are western yellow pine, sugar pine, and incense cedar, which occur in mixture with each other and with other species such as Douglas fir and white fir.

UTAH EXPERIMENT STATION.

This station was organized in the fall of 1912 on the Manti National Forest, chiefly for the purpose of carrying on intensive grazing studies, especially studies of the effect of grass cover and grazing upon floods, erosion, and purity of the water supply. Since this station is located in the Wasatch range of mountains in the midst of vast areas of aspen, opportunity is afforded also for carrying on silvicultural investigations in the management of aspen stands and their replacement by conifers.

ARLINGTON FARM, WASHINGTON, D. C.

The work at the Arlington farm is limited to seed tests in the greenhouses of the Bureau of Plant Industry and to basket-willow studies, propagation of different varieties of willows, and raising small quantities of basket-willow rods of the recognized commercial species. It is not, therefore, a forest experiment station in the sense all other stations are.

The experiment stations in the different districts do not attempt to duplicate the work of each other, but each aims to concentrate on problems most typical and most urgent in the district in which it is located. Examples of this are as follows:

District 3 (including Arizona and New Mexico) has a problem of the first importance in the study of the western yellow-pine forest, its management and reproduction. The investigations in this district are therefore chiefly directed to the solution of such problems. All other districts have western yellow pine which enters more or less into the management of their Forests, but to a less extent than in District 3.

In District 2 (Colorado and Wyoming) lodgepole pine, Douglas fir, and Engelmann spruce form the bulk of the Forests. Their management and reforestation is therefore the main field for investigation.

In District 1 (Montana and northern Idaho) the western white pine and larch types, and to a considerable extent, also, lodgepole pine, attract especially the attention of the investigator. As far as the problems in the lodgepole-pine type are concerned, however, the investigations are divided, as far as possible, between Districts 1 and 2. Thus the investigations in District 1 are chiefly of growth, volume, and yield; in District 2, chiefly of seed collection, seed extraction, and reforestation.

In District 6 (Oregon, Washington, and Alaska) the experiments in the Douglas-fir type are emphasized, while in District 5 (California) the mixed forest of sugar pine, yellow pine, and incense cedar as well as eucalyptus problems are brought to the front.

The silvicultural investigations carried on by the Forest Service are conveniently classed under the following headings:

- Forestation:
  - General studies.
  - Seed, production, fertility, methods of extraction, etc.
  - Nursery practice.
  - Species, methods, and seasons for artificial forestation.
  - Sites—limits upon the growth of each species fixed by site conditions.
  - Introduction of exotics.
  - Species.
- Forest influences upon climate, stream flow, erosion, etc.
- Management:
  - General systems and their technical basis.
  - Methods of cutting.
  - Brush disposal.
  - Natural reproduction.
  - Thinnings.
  - Valuation—immature growth, merchantable timber, soil for forest production.
- Mensuration.

- Protection from—
  - Fire.
  - Grazing.
  - Diseases.
  - Insects.
  - Animals.
  - Snow.
- Regional studies of types and forest conditions.
- Silvical studies:
  - Distribution of forest trees and types.
  - Forest types—description, basis of tree associations, etc.
  - Special studies.
- Tree studies: Growth, yield, silvical characteristics, methods of management, etc.
- Utilization studies.

FORESTATION.

The studies and experiments in forestation cover the entire field of establishing a forest by artificial means—from the collection of the seed to the final sowing of seed or planting of trees in the field. They include investigations in regard to the collection and testing of seed; factors influencing the amount and quality of seed produced, such as site, age, and condition of the tree; periodicity of seed years; effect of the source of seed, such as the locality in which the seed was produced and the condition of the mother tree, upon the size and hardiness of the seedlings. They cover experiments in the nursery as to the time of sowing, depth of covering, necessity for shade, protection from birds and rodents, age at transplanting, methods of transplanting, use of fertilizers, etc., for the various species, also experiments in seed sowing and planting of nursery and forest-grown stock to determine the comparative values of each for the various species and sites, as well as the best seasons, the best age of stock, methods of sowing and planting, the possibility of extending the range of native species, or of introducing exotics.

SEED INVESTIGATIONS.

The extensive seed collecting and seed extracting operations now carried on by the Forest Service called forth an important line of experiments with seed. This included methods of collecting, cleaning, extracting, testing, and storing of seed. The technique of handling large quantities of cones and of handling the seed receive special attention, since it is felt that this work, involving the expenditure of thousands of dollars, must, by all means, be on a scientific basis.

From the tree to the final storage room seed under artificial treatment is liable to a great many injuries in careless hands. The problems have not been thoroughly worked out by commercial seed dealers because the demand for forest tree seed has been small. Even the procedure worked out by European foresters can not be closely followed in handling our native species, such as lodgepole pine or western

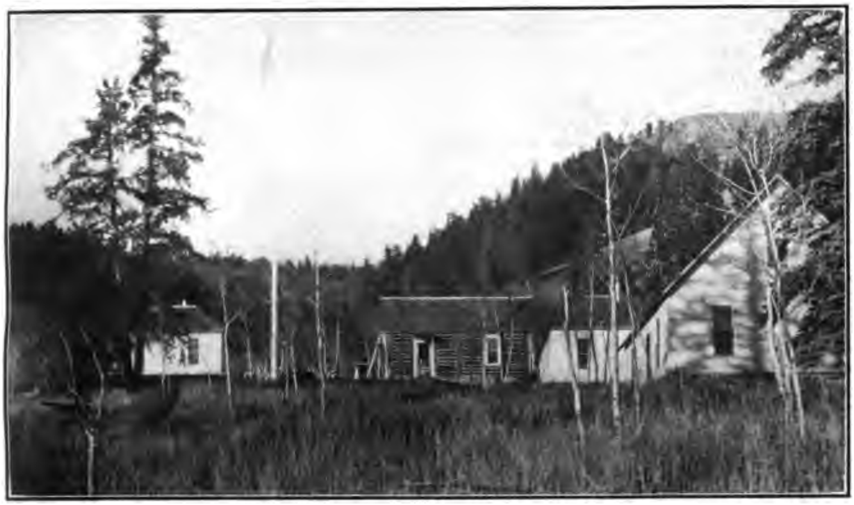


FIG. 1.—HEADQUARTERS OF THE WAGON WHEEL GAP EXPERIMENT STATION.

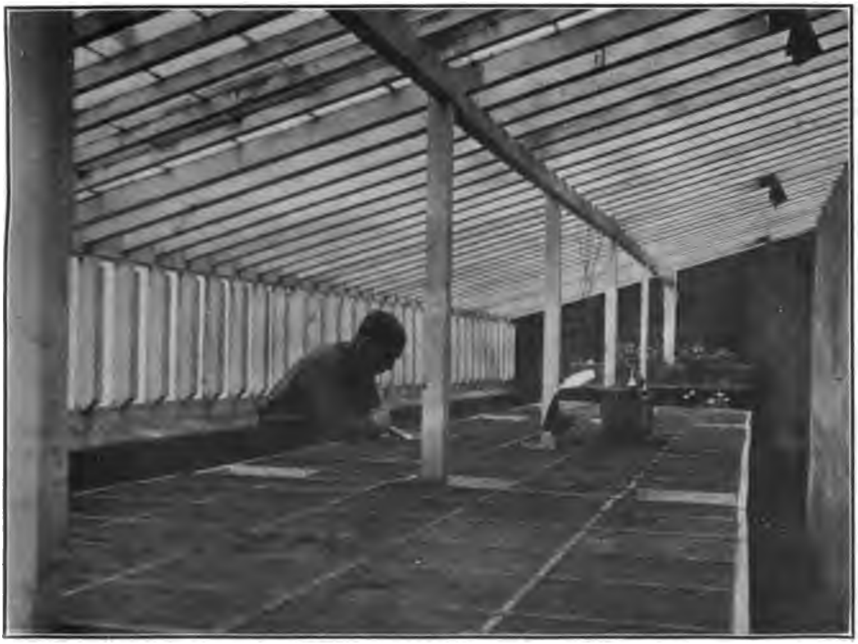


FIG. 2.—INTERIOR VIEW OF GREENHOUSE AT FREMONT EXPERIMENT STATION, WHERE SEED TESTS ARE MADE FOR THE DISTRICT.

5. In the introduction of species to a new region, such, for instance, as the Nebraska sandhills, where all forest trees may be considered as exotics, many unexpected natural enemies make their appearance. Probably the most important factor in success or failure, however, is climate. Despite all efforts to care for seedlings in the nursery, to protect them from disease, excessive light, and drought, and despite the efforts to make the conditions at the time of planting as favorable as possible, results so far obtained indicate that in a given situation only a certain proportion of the orginal number of seedlings of any species will survive. Failure to adapt to new conditions is the only possible explanation. Can the quality of adaptability, or original hardiness, be traced to the parent trees?

These problems are only different phases of one problem—when and how shall the seed for reforestation work be selected?

A number of experiments to answer these questions are now carried on at the different experiment stations. In order to yield conclusive results, however, these experiments will have to be carried on for several years.

NURSERY PRACTICE.

Experiments in nursery practice are confined to raising stock in the nursery. There are many problems in the handling of a forest-tree nursery in a given region which must be determined for that particular nursery. To accept the findings of an investigator who has worked with entirely different conditions of soil, climate, and tree species may be worse for the nurseryman than to be ignorant of any such investigations. For instance, nursery practices which have proved very successful in the New York State nurseries have been almost disastrous when attempted under the absolutely different conditions of the Halsey nursery, Nebraska. There are practices which would be bad under any conditions, others which with discretion might well be applied anywhere, but for the most part each nurseryman must work out his own problems.

SPECIES, METHODS, AND SEASONS—SITES.

Experiments with species, methods, and seasons, as well as with sites, are designed to determine what measure of success may be expected from different species and methods for planting or sowing on various sites. With respect to the latter point, the problem is mainly one of determining where the efforts may be best applied in the hope of encouraging the reforestation work on favorable sites, and it will usually follow, too, that the site which is most favorable for sowing and planting will produce the best timber in the shortest time. On the other hand, situations most in need of a protective forest are usually the most difficult to stock.

The methods of procedure in sowing and planting must be thoroughly worked out on a small scale in order to execute larger operations, which are much needed, most economically. The importance of this line of work can not be overestimated, nor should the value of small, carefully studied experiments be deprecated. Viewed on the basis of present plans for reforestation work, and the experience gained at experiment stations during the last few years, a thousand dollars expended in experimental work at two or three points would furnish a knowledge of methods and seasons for sowing a given species, while in a single year $10,000 might be expended without results if the work happened to be done at the wrong time or in the wrong way. The value of any method of sowing or planting must be judged entirely by the results which it produces, or, in short, the number of trees established in a new site, for each dollar expended.

The numerous problems encountered in the reforestation work, the solution of which is being attempted, may be grouped as follows:

1. Effect of situation (slope, aspect, etc.) on success of sowing and planting.
2. Effect of herbaceous, shrubby, or arborescent cover on the success of sowing or planting.
3. Effect of grazing on the work of reforestation.
4. The best season for sowing and planting.
5. The best methods of sowing and planting, or comparison of both processes, including the preparation of ground.
6. The best kind of stock for planting (in a given species).
7. The destruction of rodents, and other means to insure the success of sowings.

The best methods of reforestation and the most favorable season for sowing seed and planting nursery stock are being tested with all important trees upon the National Forests.

STUDIES IN RANGE EXTENSION AND INTRODUCTION OF EXOTICS.

Within the National Forests, as well as outside of them, in the mountainous regions, the several forest types are found in distinct altitudinal zones.

The chief differences between successive zones lie in the amount of precipitation which they receive and, less important, in a decreasing mean temperature toward the higher altitudes. To what extent the amount of moisture present in the soil and the temperature absolutely limit the altitudinal range of a species and to what extent this limitation of range of any species is due to the more successful competition of another species is still a matter of speculation. It is believed that any species is capable of adapting itself to less moisture on the one hand and lower temperature on the other than are found in its native habitat. Such being the case, it is possible that yellow pine and

Douglas fir, for instance, by far the most valuable of the four principal species concerned in the Rocky Mountains, can be made to grow in place of the less valuable piñon on the one hand and the less valuable Engelmann spruce on the other. It goes without saying that this is a problem in reforestation to be considered where there is to be no competition between the natural species of the type and the species whose range is extended into that type. In other words, can we not create temporary types in reforestation more valuable than the natural types?

To answer this question, two experiments have been inaugurated at the Fremont Station with the extension of Douglas fir by artificial sowing and planting to higher altitudes and with the extension of yellow pine to lower altitudes. These experiments, if serving no other useful purpose, will furnish more definite information than is yet available regarding the climatic limitations of successful reforestation.

What is true of altitudinal range is also true of geographic range. There are many species which occur in some National Forests and are absent in others, although the climatic and other physical conditions may be nearly the same. Thus, lodgepole pine is absent from the southeastern portion of the Rocky Mountains, yet there are many localities where it could apparently grow well.

Experiments were instituted in several of the National Forests, and especially in the Fremont Experiment Station, for the purpose of determining the possibility of introducing, by means of sowing and planting, such species as eastern white pine (*Pinus strobus*), western white pine (*Pinus monticola*), lodgepole pine, Norway pine, and several others which do not occur there naturally, but whose climatic requirements do not differ essentially from the other species growing in those localities.

While the Forest Service is not directly concerned with the introduction of any foreign species into this country, and believes that our own forest flora is so rich in species that it is possible to find trees practically for any situation and soil, yet there are a few species abroad the advantage of which is so evident that the Forest Service carried on several experiments for the purpose of determining their suitability in this country. Among the species are cork oak, maritime pine, Austrian pine, European larch, Norway spruce, Scotch pine, eucalypts, and acacias (wattles).

FOREST INFLUENCES.

Experiments in forest influences aim to determine the relation of forests to climate and stream flow and also to obtain data necessary for a proper understanding of all other silvicultural experiments in which the climatic factor enters into the results. The essential fea-

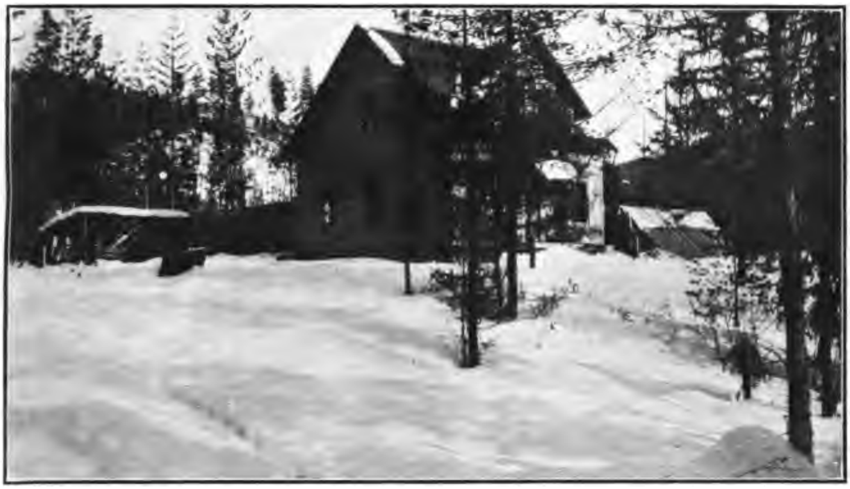


FIG. 1.—PRIEST RIVER EXPERIMENT STATION, IDAHO, LABORATORY AND OFFICE BUILDING.

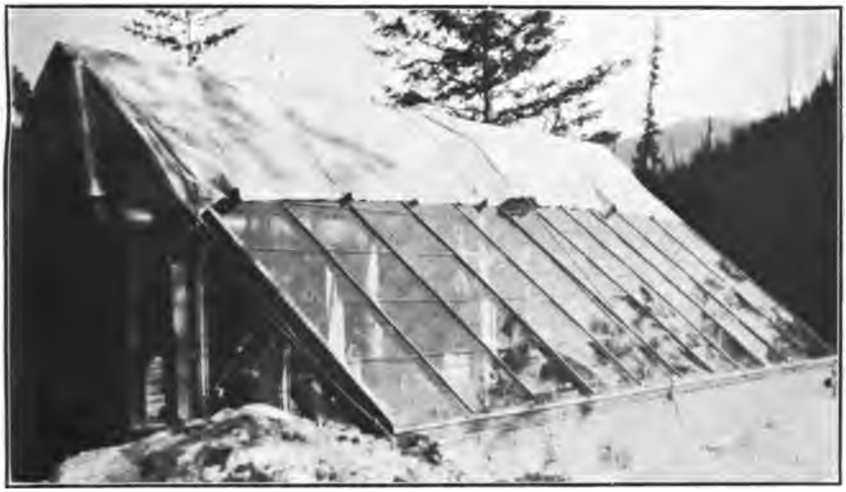
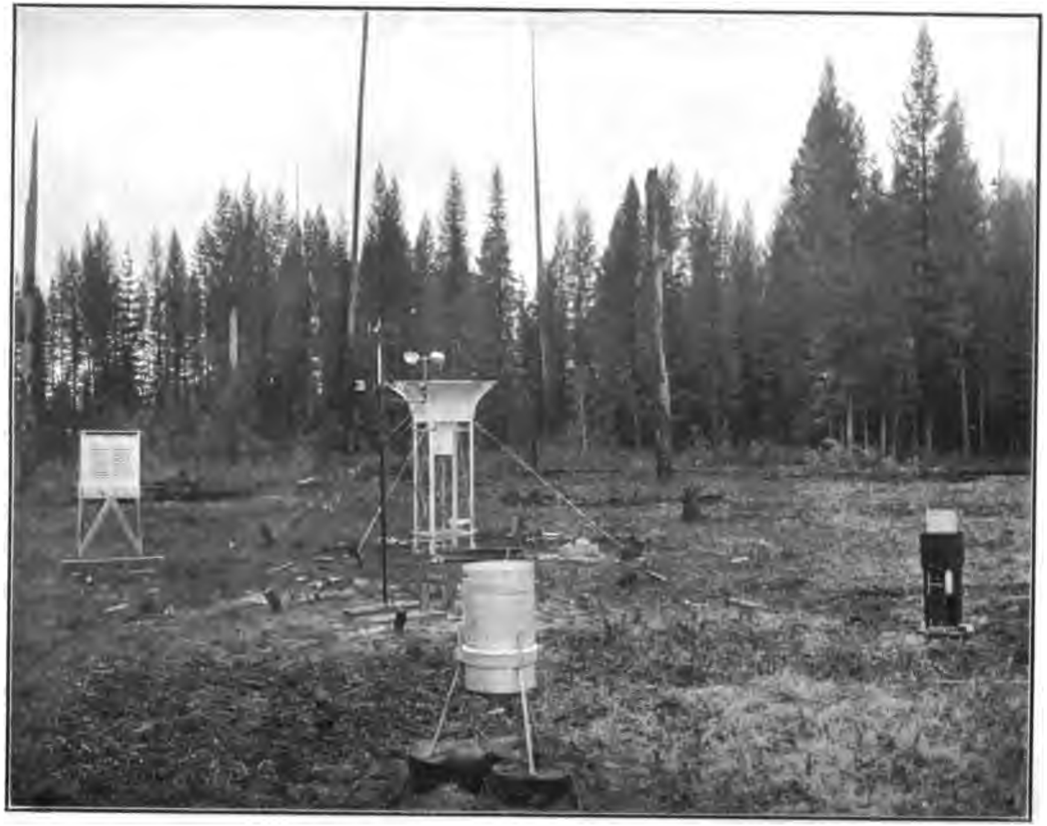


FIG. 2.—PRIEST RIVER EXPERIMENT STATION GREENHOUSE.

PLATE VIII.



CONTROL METEOROLOGICAL STATION ON BENTON FLAT, PRIEST RIVER EXPERIMENT STATION. IN BACKGROUND AN EVEN-AGED STAND OF 50-YEAR-OLD WESTERN LARCH. SITUATION REPRESENTATIVE OF THE LARCH TYPE OF NORTHWESTERN MONTANA AND IDAHO.

tures of these experiments are meteorological observations arranged in such a way as to bring out the relation between vegetation, climate, and stream flow. These observations are carried on in cooperation with the United States Weather Bureau. The cooperative plan agreed to by the Weather Bureau provides that it shall furnish the instruments for observations of air, temperature, humidity, precipitation, and wind velocity. In most cases three sets of instruments are installed at the same experiment station, either in different forest types or in the forest, on the edge of the forest, and in the open.

One of the most important forest influences is considered to be its effect upon stream flow.

There is still some skepticism as to the great value of the forest cover in retaining the water of precipitation and preventing its rapid run-off. The results of European investigation of this and other matters concerned with the indirect influence of the forest must not be taken as final, or even as having very great bearing on the question as presented in this country. The fact that Europeans have found very little difference between the climate inside and that outside the forest, that they have noted no great change in the flow and quality of their streams, etc., is easily accounted for on the ground that their observations have covered no great range of climatic conditions, and that they have practically all been made since the time when the forest area assumed its normal position in the balance. No such extremes of climate as this country possesses, or such a change in the forest cover as has been witnessed here in the past century, are to be imagined for any country in Europe, and hardly for the whole continent. The study of the effect of forest cover upon stream flow is studied at the Wagon Wheel Gap Station, which has been established entirely for this purpose. The object of the stream-flow experiment as it is conducted on the Rio Grande National Forest is to determine by means of the most highly accurate measurements the effect of forest cover upon the high and low water stages of mountain streams, the total run-off from mountain watersheds as compared with the annual precipitation, and the erosion of the surface of such watersheds. The measurements of factors concerned are so made as to furnish in a general way an estimate of the relative amounts of run-off and evaporated water of each watershed. Since, as has been shown by geological examination, there is very small possibility of an escape of the water of precipitation, by percolation, other than through the main channels of the streams involved, there is no third element to be measured.

In the present case the comparison of the forested and nonforested mountain watershed is obtained in a manner which can not fail to give convincing results. Measurements of the streams in two watersheds, both moderately well covered with forest, will be conducted for a number of years with the measurements of all the factors which may affect the character of the flow of each stream. By this process a certain relation will be established between the two streams for different sets of conditions of different characters. For instance, it will be found that a given amount of precipitation produces in one watershed a flood of a given height and in the other watershed a flood of slightly different height, but both influenced by forest covers of practically the same character. Or, again, a given amount of snow melting under a given maximum and mean daily temperature of air and soil produces a given flow in each stream. When this comparison has been carried long enough to furnish a number of relations between the two watersheds, one watershed will be denuded and the forest cover upon the other will be retained. There will be, therefore, upon the forested watershed the same conditions affecting the flow of the stream in that watershed as during the earlier part of the experiment, while upon the denuded watershed the conditions will have been changed only so far as forest cover is concerned, and any changes in the relative behavior of the two streams as before and after the denudation must therefore be accredited to the change in forest-cover conditions. To cite a hypothetical case: With the forest cover on both watersheds a rainfall of 1 inch in 1 hour produces a flow in the watershed A of 1 foot of water over the weir, the crest of the flow occurring 2 hours after the beginning of the precipitation as recorded by the time record at the head of the watershed and automatic stage register at the measuring point of the stream. In watershed B the same precipitation produces a flow of 15 inches over the weir, occurring 1¾ hours after the beginning of the storm. The two streams during the progress of this flow deposit an equal amount of silt in the settling basins as measured by actual weight, and samples of the water passing out of the basins are shown to be carrying the same amount of finer silt which does not settle.

After the denudation of watershed B, a similar storm produces in watershed A a similar flow as regards volume and time, while in watershed B it produces a flow of 20 inches, occurring 1½ hours after the beginning of precipitation, and it is found that a much larger amount of silt has been deposited in the settling basin.

It must be admitted that such comparative records as these, whether or not they prove the contention as to the value of forest cover in retarding run-off and preventing erosion of the slopes of watersheds, must carry conviction which can not fail to be of assistance toward a proper understanding of the value of mountain forests.

MANAGEMENT STUDIES.

The purpose of these studies is to determine the best methods of cutting in the different forest types in order to secure natural reproduction in the shortest possible time. The most economical and best method of reforestation is, of course, by natural seeding from the trees left on the cut-over land or from trees adjoining the cutting. These studies include also experiments in assisting natural reproduction by various methods of brush disposal, destruction of unfavorable ground cover, soil preparation, and other means. By the study of cut-over areas in which there is already partial reproduction much time may be saved in obtaining results. The old cuttings, however, did not follow any distinct silvicultural systems, and few, if any, followed the systems which we may hope to adopt in the future. For the most thorough studies, therefore, it is necessary to select small areas of timber sales and follow out an ideal system of cutting, sometimes at slight additional expense, since it is frequently necessary to overreach the terms of the contract under which the main cutting is being done. While a fair beginning has been made in experiments of this character, there are few results available as yet, since it will take several years before the effect of one or another method of cutting will show itself upon the success or failure of natural reproduction.

Studies in management include further experiments in thinnings to determine the effect of improvement cuttings on the volume and quality increment of the remaining trees for various exposures, types, and species with special reference to the relation of the cost of such thinnings to the value increment. While thinnings as a distinct cultural operation will be hardly applicable yet for many years in most of our forests, there are types where the removal of certain classes of trees is practicable at present and is of benefit to the remaining stand. Such stands are found in the lodgepole pine, Douglas fir, and in some instances also in the yellow pine types. Thinning experiments are now conducted on a number of Forests, especially in Districts 1 and 2.

Methods of determining the value of land for agricultural or forest purposes, and of ascertaining the damage caused by fire to immature or mature stands, form also a part of management studies. While there are definite mathematical formulas for calculating the productive capacity of the soil and the value of immature timber, the application of the formulas depends on many factors, such as the rotation adopted for the different species, stumpage prices, cost of natural or artificial reforestation. These factors must be carefully studied before we can be certain that the formulas used answer the present economic conditions of forestry in this country.

MENSURATION STUDIES.

The proper handling of timber sales as well as the management of the forests must necessarily be based on reliable data as to the growth, volume, and yield of the different species and types of forests. They are also essential for determining the damages caused by fires, trespass, etc. The purpose of growth studies is first of all to collect such data, and from them to establish certain laws of tree growth. In addition, studies in mensuration include comparison of different methods of gathering data; for instance, whether the accretion borer or stump analysis should be used for determining the rate of growth, tape or calipers for standing trees on sample plots, strip surveys, or ocular estimates for determining yield in reconnaissance work. The work of collecting growth and yield data is carried on largely in connection with the reconnaissance work in the districts and is confined to timber-sale areas which afford the best opportunity for measuring large numbers of trees, and to permanent sample plots which present the best means for measuring the growth of standing timber. Such data are also collected in connection with tree studies.

To the growth and yield studies belong also the establishment of permanent sample plots. The purpose of the sample plots is to have in forests typical for a given region and species definitely and distinctly marked areas on which all the trees are carefully measured and within which certain silvicultural operations, such as thinnings, improvement cuttings, etc., are made. These areas are measured at definite intervals for each experiment, and the results of thinning, opening up of the forest, or removal of the litter which find their expression in the growth of the trees are studied. These areas at the same time furnish yield data, that is, the amount of timber that can be secured from forest land at certain ages of the stand. Most of the sample plots are now established on the National Forests in connection with other studies. In the East sample plots were established on State and private land, and many of them which were established five years ago were recently remeasured. While these sample plots are extremely valuable in themselves, they are also used in connection with other studies, such as tree studies or the best methods of handling timberlands or farmers' woodlots. The sample-plot method is the most reliable one for studying forest problems, and furnishes the basis for American forest management.

PROTECTION STUDIES.

These studies aim to ascertain the extent of the effect caused by fire, grazing, diseases, insects, animals, and climatic agencies, such as snow, hail, and wind, upon standing timber and natural reproduction. The studies of the effect of grazing form a part of the grazing studies conducted by the Branch of Grazing and are taken up more fully under the head of Grazing. The object of these investigations is to secure definite data in regard to actual amount of damage done to natural reproduction by grazing, and of devising a system of range control whereby the damage may be minimized without the total exclusion of stock. The relation of grazing to fire protection, the use of goats for destroying chaparral, and thus preparing for reforestation are among the problems taken up under this head.

While the investigations of the diseases of trees are under the direction of the district pathologist of the Bureau of Plant Industry, much information is being collected by the Forest Service as to the effect and extent of various tree diseases, such as rot, mistletoe infestation, witches' brooms, leaf and seedling diseases. Similarly, while the investigations of insect infestations are in charge of the Bureau of Entomology, studies of the actual insect control, the location and extent of infested areas are carried on by forest officers. Specimens of injurious insects, together with specimens of their work, are collected and forwarded for identification to the Bureau of Entomology.

Habits and detrimental or beneficial effects of wild animals upon forest growth, damage by rodents and birds in destroying seed or seedlings, and methods of combating such animals are a part of the studies conducted under Forest Protection. These studies are carried on in cooperation with the Biological Survey, which decides upon the most effective methods of combating the animals.

REGIONAL STUDIES.

Regional studies aim to secure authentic information concerning the forest resources of State or forest regions. They deal with problems peculiar to the region or State and are therefore of direct benefit to the timber and woodlot owners of that State or region. Most of the studies are carried on in cooperation with the States and are published by the States. The regional studies provide information applicable to the timberland or woodlots within that region. This enables the Forest Service, in advising the individual timber or woodlot owner, to do away to a large extent with the necessity of examining each individual woodlot. Aside from the practical value of such regional studies they contribute to a more exact and fuller knowledge of the forest resources of this country and their distribution.

SILVICAL STUDIES.

The proper aim of silvical studies is to establish a definite relation between the forest region, forest types, and forest trees in general, and the climatic and physical factors affecting their distribution and growth. Silvical studies are, therefore, largely forest ecological studies. The silvical studies proper are largely concerned with the studies of types, their origin, characteristics, permanence, and their development from the seedling stage to maturity. They seek to correlate the vegetative phenomena of tree growth, such as leafing, flowering, seed ripening and dissemination, and leaf falling, with climatic factors. They attempt to determine soil, moisture, and light requirements of the different species and the methods of determining these requirements of forest trees. These studies are basic and form the foundation upon which the practical application of the silvicultural methods must rest.

TREE STUDIES.

The purpose of tree studies is to secure information concerning the important forest trees of this country as a basis for their proper management. The results of such studies appear as monographs dealing with the range of each tree, its silvical characteristics, yield, and management.

The studies of individual trees in the forest embrace those points usually included in a silvical study, habitat, silvical characteristics and requirements, form, volume, growth, seeding capacity, enemies and diseases, phenology, etc. The requirements of trees are studied not only by general observations but by actual measurements of the physical factors in which they are growing, and the results are expressed as far as possible in absolute figures. Thus, in studying the light or moisture requirements of a species the actual light intensity or water contents of the soil in which it grows is measured.

UTILIZATION STUDIES.

While problems in the utilization of timber are best handled by the Madison laboratory, yet the field studies in silviculture also present many opportunities for experimentation along this line. The vast areas of fire-killed timber bring up the question as to the length of time during which the fire-killed timber may still remain serviceable and therefore merchantable. The rapidity and the causes of deterioration of fire-killed timber is of vital interest, and studies to determine these facts are now carried on in a number of National Forests, especially within the area visited by the disastrous fires of 1910.

Since it is frequently necessary to leave mature or overmature trees for seed production, it is important to know how long such trees will continue to bear seed and how soon they will become unmerchantable. To this end records are established at several of the experiment stations on a number of trees in various stages of decadence. The records include the number, location, diameter breast high, crown and bole description, and effects for each individual tree.

Aside from the utilization studies there is a distinct field for silvical investigation in connection with the studies of the technical qualities of wood. There should be established a definite relationship between the technical qualities of timber and conditions of their growth—various altitudes, soils, and slopes. This relationship would enable such handling of the growing forest as to secure the most desirable qualities by means of silvical operations.

THE PROGRAM OF INVESTIGATIVE WORK FOR 1912.

In accordance with the investigative organization adopted this year a program of investigative work for 1912, submitted in the prescribed manner, has been approved by the Forester. This program includes 353 investigative projects.

DEFINITION OF A PROJECT.

In preparing the Service program each investigation having a single object but involving one or several similar operations was considered a distinct project. The object, however, must not be too minute, but must aid at the solution of some problem of broad importance. What is considered as a project can best be shown by the following examples: In reforestation work all methods of sowing or planting the same species at different times of the year in a single district were included under one project. Thus yellow-pine sowing or planting by different methods and at different seasons in District 2 constitutes a single project. In products work all tests of mechanical properties of wood, based upon small specimens from commercial species in the United States, are classed as one project, not the tests on each individual species.

By thus combining as one project a number of operations having the same object, an opportunity is afforded to correlate the results and arrive at more definite conclusions than if each operation is considered separately. The final determination of what constitutes a problem of sufficient importance to class as a project must rest with the administrative officers directing the work.

The program of work, as approved, is given below:

DENDROLOGY.

A.—DESCRIPTION AND DISTRIBUTION OF NORTH AMERICAN TREES AND SHRUBS.

Project.	Object.
Forest trees of the United States: Rocky Mountain region, Northeastern region.	To bring together in a comprehensive manner all the available information on botanical and silvical characteristics of forest trees by regions.
Shrubs of the United States.	To bring together all available information on the botanical characters of shrubs for the purpose of identification.
Forest distribution studies...	To determine the geographic distribution of North American trees and shrubs.
Study of the forest flora. (Herbarium.)	To collect specimens of different species of forest trees and shrubs for use in dendrological and silvical studies, and in the identification of specimens which are sent in, and also for supplying the Washington and district herbaria with a full set of specimens.

B.—IDENTIFICATION OF NORTH AMERICAN FOREST TREES.

Wood structure.

Distinguishing characteristics of the wood of North American trees: North American walnuts, sycamores, elms, pines, hickories, jack pine, red pine.	To determine the structural and other distinguishing characters of different species and groups of woods for the purpose of identifying them.
Hand collections of 75 species of commercially important North American woods for distribution to educational institutions and to Forest districts.	To furnish collections to schools and districts.

General.

Identification of seedlings and mature catalpa trees by means of the wood structure and external characters.	To determine reliable means for identification of the wild and cultivated species of catalpa.
The distinguishing characters of turpentined pine woods of the South.	The identifications of wood from trees that have been turpentined.

C.—IDENTIFICATION OF EXOTIC FOREST TREES.

Wood structure.

Project.	Object.
Distinguishing characteristics of Circassian walnut wood.	To determine the structural characters which distinguish this wood from common substitutes.
Distinguishing characteristics of tropical and subtropical woods:	
True mahogany	To furnish information on the distinguishing characters of the different grades of true mahogany wood.
Panama woods	To furnish information on the distinguishing characters of commercially important woods of the Panama zone.
Greenheart	To furnish information in regard to the distinguishing characters of greenheart wood.

D.—SPECIAL STUDIES.

Pith flecks in North American woods.	To determine the cause of pith flecks in North American woods and their value as distinguishing characters.

GRAZING.

A.—ARTIFICIAL RESEEDING.

Restoration of overgrazed areas and improving the quality of forage by artificial reseeding with cultivated plants.	To determine under what conditions seeding can be successfully undertaken, methods of seeding, time of seeding, amount of seed, cultural treatment, and methods of handling the lands during the restocking period.
Introduction of forage plants in the Southwest.	To determine the possibility of improving range conditions in District 3.
Relation of soil acidity to artificial reseeding.	To determine (1) cultivated species best adapted to acid soils; and (2) how to recognize strongly acid soils by character of native vegetation.
Cultivation of indigenous forage plants with a view to their use for artificial reseeding of the range.	To carefully select a few promising native forage plants, collect seed in native habitat, put it under cultivation at Forest experiment stations, and to determine the possibility of securing seed for distribution at a cost not prohibitive.

B.—NATURAL RESEEDING.

Restoration of overgrazed areas by the natural reseeding of native forage plants.	To determine (1) the possibilities of naturally reseeding depleted lands that still have part of the stand of native vegetation; and (2) to devise a system of grazing which will accomplish this result if possible.
Rotation grazing	To study the practical application of a rotation system of grazing developed as a result of the preceding study to determine more fully (1) the advantages of this system, over existing systems, to the range and to the stock; and (2) to what extent it can be applied in the practical management of Forest ranges.
Range improvement by natural reseeding.	To determine the possibility of increasing carrying capacity of much depleted range on Hayden Forest without total restriction of grazing.

C.—DISTRIBUTION AND ECONOMIC IMPORTANCE OF FORAGE PLANTS.

Project.	Object.
Life history, forage value, and ecological requirements of important forage in the mountains of northeastern Oregon.	To determine the entire life cycle of important forage plants in this locality as a basis for judicious management of the grazing of lands supporting these plants.
Distribution, life history, and economic importance of forage plants.	To bring together valuable information on this line collected in connection with range reconnaissance by special grazing men.
Distribution, natural habits, and economic importance of forage plants.	The collection and identification of forage plants on important grazing Forests, accompanied by notes on distribution, growth requirements, and forage value.

D.—FOREST PROTECTION (GRAZING).

[Listed under "Silviculture—Protection."]

E.—METHODS OF HANDLING STOCK.

Project.	Object.
Small coyote-proof inclosure in connection with range lambing allotments.	To determine the possibility of (1) decreasing damage to range during lambing period; (2) increasing percentage of lambs saved; (3) decreasing cost and difficulty of handling.
Improved methods of handling sheep on Forest range.	To study the practical application of results from Oregon pasture experiment to determine (1) possibility of keeping sheep away from an established camp; (2) advantages of such a system to the range and the sheep as compared with existing methods; and (3) determining how many sheep should be run in a band.
Using range without water for sheep grazing.	To ascertain (1) kind of forage; (2) climatic conditions; and (3) method of handling sheep which are essential if range without watering places is used for sheep grazing.
Carrying capacity of range...	To secure actual figures on the number of acres of range of a given type necessary to support a sheep.

F.—DEVELOPMENT OF STOCK-WATERING PLACES.

Project.	Object.
Methods of developing stock-watering places.	To bring together available data on subject to determine (1) under what conditions to develop water; (2) most efficient methods of development; (3) capacity of watering place necessary per head of stock.

G.—POISONOUS-PLANT INVESTIGATIONS (COOPERATIVE).[1]

Project.	Object.
Loco-weed disease...........	To determine (1) poisonous species; (2) under what conditions poisoning occurs; (3) antidote; (4) management of stock on poison areas; and (5) eradication of plants.
Larkspurs as poisonous plants.	Same as above.
Rubber weed as a poisonous plant.	Same as above.
Lupines, death camas, and miscellaneous poisonous plants.	Same as above.

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[1] Forest Service cooperates by selecting field stations, aiding in equipping stations, collecting information as to extent of losses and locality of loss, and to the extent of $2,000 for salary and expenses. Has nothing to do with collection of scientific experimental facts.

H.—SPECIAL STUDIES.

Project.	Object.
Reclamation of mountain meadows depleted by erosion.	To determine possibility of constructing small dams in erosion gullies, checking velocity of water, and silting up gullies.
Effect of grazing upon erosion, streamflow, and purity of water supply.	To determine the effect of grazing upon erosion, streamflow, and purity of water supply.

PRODUCTS.

A.—MECHANICAL AND PHYSICAL PROPERTIES AND STRUCTURE OF WOODS.

Mechanical properties.

Project.	Object.
Tests on small specimens free from defects.	
Mechanical properties of woods grown in the United States.[1]	To establish scales by means of which it will be possible to compare directly the bending and compressive strength, shearing, stiffness, toughness, specific gravity, etc., of the commercial timbers of the United States.
The relation between static and impact loading in testing mechanical properties of wood.	To determine the relation between static and impact loading on the mechanical properties of wood.
Tests to determine the strength of wood beams under continuously applied loads.	To determine the effect of continuously applied loads upon the mechanical properties of woods.
Tests on structural timbers.	
Tests on redwood...........	To determine the mechanical properties, and to investigate the influence of different localities on strength.
Tests on green and air-dried western yellow pine.	Same as above.
Tests on western larch.......	Same as above.
Tests on the mechanical efficiency of joints and fastenings in wooden structures.	To determine the efficiency of various types of joints and fastenings used in wooden structures.
Investigation of lumber waste in building scaffolding, and the introduction of new methods.	To secure information which will assist in reduction of waste in building scaffolds and in the possible utilization of thinnings for this purpose.
Tests on manufactured articles.	
Tests of packing boxes, in cooperation with the bureau for the safe transportation of explosives and other dangerous articles.	To determine the suitability of various types of boxes for use in the transportation of explosives and other dangerous articles, and to secure data upon which specifications and improvements in design of such boxes may be based.

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[1] Select species for test to correlate with Silviculture's commercial tree studies.

A.—MECHANICAL AND PHYSICAL PROPERTIES AND STRUCTURE OF WOODS—Contd.

Mechanical properties—Continued.

Project.	Object.
Tests on manufactured articles—Continued.	
Tests of poles	To determine the comparative strength and stiffness of various species which are not now used extensively for poles, but which are believed to be satisfactory for this purpose.
Study of wood which may be used as substitute for dogwood and persimmon for the manufacture of shuttles.	To determine what woods are suitable substitutes for dogwood and persimmon for use as shuttles.
Effect of preservative treatments, etc., on strength.	
Effect of commercial processes of creosoting on the strength of structural timbers.	To determine the effect on the strength of southern yellow pine and Douglas fir bridge stringers of treating with creosote by the Bethell and boiling processes.
Effect of mechanical operative features of pressure wood-preserving plants on the strength of wood.	To determine the effect upon the strength of wood of the various steps and manipulations of commercial wood-preserving processes.
Relative efficiency of various wood preservatives.	To determine, in conjunction with other experiments to be conducted under this project, the effect of various preservatives on the strength of wood.

Physical properties.

Fundamental properties.	
Specific heat and heat conductivity of wood.	To determine the specific heat and heat conductivity of different woods.
Penetrability of woods to liquids and gases.	To secure information on the exact ways in which liquids and gases penetrate wood and wood substances.
Relation of the hygroscopic condition of wood to temperature and vapor pressures.	To determine the hygroscopicity of wood, or its relation to atmospheric moisture at various temperatures.
Determination of the heat of absorption of water in wood.	To secure a short method to determine the relative hygroscopicity of various woods.
Specific gravity of wood substance.	To determine the specific gravity of wood substance.
Conditioning experiments.	
Air seasoning of structural timber.	Correlate, analyze, and compile all available data on this subject.
Experiments with small single chamber experimental kiln.	To determine the best methods for controlling the humidity and temperature conditions in the kiln with different forms and species of lumber.
Experimental operation of a continuous chamber dry kiln of commercial size.	To determine the best methods for controlling the humidity and temperature conditions in a continuous chamber dry kiln of commercial size.

A.—MECHANICAL AND PHYSICAL PROPERTIES AND STRUCTURE OF WOODS—Contd.

Physical properties—Continued.

Project.	Object.
Conditioning experiments—Continued.	
Operation of single chamber dry kiln of commercial size.	To determine the best methods for controlling the humidity and temperature conditions in a single-chamber dry kiln of commercial size.
Study of commercial processes used in kilndrying.	To secure information regarding the present commercial practice in use at various types of kiln in various sections of the country.
Analytical study of artificial methods of drying wood.	To determine the effect on wood of subjecting it to high temperatures and pressures, and to various conditions of the surrounding medium, and the investigation of the fundamental factors in the treatment and seasoning of woods.
General studies.	
Temperature changes in wood under treatment.	To determine the temperature changes which occur in wood when subjected to various conditions and temperatures of the surrounding medium.
Experiments in gluing black-gum lumber.	To determine methods of seasoning and conditioning which give best results in gluing black-gum lumber.

Structure.

Correlation of the microscopic structure of commercial woods with their properties and uses.	To determine the relation of the structure of woods to its properties and uses.

B.—WOOD PRESERVATION.

Preservatives.

General.	
Tests of the comparative efficiency of various wood preservatives.	To determine the relative efficiency of various preservatives which are in commercial use or proposed.
Efficiency of various fractions of coal-tar creosote in protecting southern yellow pine from marine borers.	To secure data on the comparative value of fractions of creosote in preventing the ravages of marine borers.
Investigations relating to problems connected with the use of treated wood-block pavements.	To secure information which will assist in solving the problems which confront the wood-block paving industry.
Physical and chemical properties.	
Classification of authentic creosotes.	To determine the composition of creosotes obtained from commercial tars in this country in order to correlate the methods of production with their composition and properties, and to develop methods by which the important differences in composition can be distinguished.

B.—WOOD PRESERVATION—Continued.

Preservatives—Continued.

Project.	Object.
Toxicity.	
Toxicity of preservatives with pure cultures in Petri dishes and jars.	To determine the relative toxicity of various preservatives which are in commercial use or proposed.
Fungicidal properties of coal-tar creosote fractions.	To secure data on the comparative fungicidal properties of the various fractions of coal-tar creosote.
Processes new or proposed.	
Boucherie experiments on the Eldorado National Forest.	To determine a cheap and efficient method for treating poles where costly preservatives can not be economically secured.
Boucherie experiments on loblolly pine.	To determine the practicability of using the Boucherie method of treatment with loblolly pine.
Effect of varying conditions during treatment.	
Experiments on mechanical operative features of pressure wood-preserving plants. (Project 119.)	To investigate the effects of the various operations on the absorption, penetration, and other features of the treatment of wood.

Suitability of species.

Resistance to impregnation with preservatives.	
Relative resistance of commercial angiosperms to injection with creosote.	To classify the various species according to their relative resistance to creosote.
Relative resistance of commercial gymnosperms to injection with creosote.	Same as above.
Relative resistance to decay.	
Relative resistance of untreated woods to decay by pure cultures of fungi in jars.[1]	To secure data which will show the comparative durability of different species of woods grown in the United States.
Determination of the minimum and maximum moisture content of wood which permits the growth of fungi.	To secure data which will show the limits of moisture in wood which are necessary for the development of wood-destroying fungi.

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[1] In conducting these experiments and in the preparation of bulletins an attempt should be made to correlate and combine the results with those secured by the experiments of the forest pathologists on the National Forests.

B.—WOOD PRESERVATION—Continued.

Cooperative field work and service tests.

Project.	Object.
Service tests.	
Inspection of treated and untreated timbers of various forms placed under actual conditions of service.	To determine under actual conditions of service the comparative efficiency of various forms and species treated with different preservatives and processes and untreated. Includes inspection of treated and untreated ties, poles, posts, mine timbers, paving blocks, etc., of various species placed for test purposes.
Durability data on untreated fence and pole lines on the National Forests.[1]	To secure data on the length of service of untreated post and pole lines constructed on the National Forests.
Service tests on treated and untreated eucalyptus crossties.	To secure data on the suitability of this species for ties.
Service tests on treated and untreated Douglas fir ties.	Same as above.

C.—DERIVED PRODUCTS, OR PRODUCTS DERIVED FROM WOOD, BARK, LEAVES, AND THE GROWING TIMBER.

Pulp and paper.

Mechanical or grinding processes.[2]	
Pulp-making qualities of various species of wood other than spruce.	To determine the value of different species for the production of ground-wood pulp.
Fundamental laws of grinding.	To determine the effect of pressure, speed, surface of stone, temperature of grinder, diameter of wood, and length of time wood is seasoned on the horsepower per ton, production per day, and quality and yield of pulp, using spruce as a species.
Effect of using different natural and artificial pulp stones on the quality and production of pulp.	To determine the effect of the Lombard (natural), Walker (artificial), and Hercules (artificial) grinding stones on the horsepower per ton, production per day, and quality and yield of pulp, using spruce as a species.
Effect on ground-wood pulp of steaming or cooking the wood.	To determine the effect of steaming and cooking the wood in different ways upon the production, horsepower, and quality and yield of pulp secured.
Chemical processes.	
Comparative pulp-making tests on various woods.	To determine the value of different species for pulp produced by the soda, sulphite, and sulphate processes, and the suitability of the pulps for various grades of paper. The following species to be tested in 1912: Redwood and its bark, red fir, lodgepole pine, weathered tamarack, jack pine,

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[1] In carrying out these experiments, cooperation with the experiment station in the district should be secured.

[2] The individual experiments listed under this heading will all be conducted more or less jointly; that is some of the data secured from one experiment will be of assistance and use in the other experiments. It is important that the various projects be conducted together and at very nearly the same time.

C.—DERIVED PRODUCTS, OR PRODUCTS DERIVED FROM WOOD, BARK, LEAVES, AND THE GROWING TIMBER—Continued.

Pulp and paper—Continued.

Project.	Object.
Chemical processes—Contd.	
Fundamental cooking conditions in the soda process.	To determine the effect of the fundamental cooking conditions on the yield and qualities of pulp, cost of production, and consumption of wood and chemicals, aspen to be used as a standard species and results to be checked with other species.
Study of the fundamental cooking conditions in the sulphite process.	To determine the effect of the fundamental cooking conditions on the yield and qualities of pulp, cost of production, and consumption of wood and chemicals, white spruce to be used as the standard species and results to be checked with other species.
Study of the fundamental cooking conditions in the sulphate processes.	To determine the effect of the fundamental cooking conditions on the yield and qualities of pulp, cost of production, and consumption of wood and chemicals.
Effect of mechanical treatments on the quality of chemical pulps.	To determine the effect of various mechanical treatments of chemical pulp on its quality.
Effect of preliminary treatments with steam and vacuum on the cooking of chemical pulps.	To secure data on the effect on chemical pulp of preliminary treatments prior to cooking.

Wood distillation.

Hardwoods.	
Destructive distillation of hardwoods.	To determine the yields of valuable products which can be obtained by the distillation of various species of hardwoods not used for this purpose at present. The following species to be tested in 1912: Birch, maple, and beech (tested for purposes of comparison with other species); oak, red gum, hickory, and chestnut.
Methods for increasing the yields of valuable products in the destructive distillation of hardwoods.	To determine what methods will result in the greatest yield of valuable products secured in destructive distillation of hardwoods.
Study of the refining methods for hardwood distillates.	To determine best methods for refining hardwood distillates in order to secure the greatest quantity of valuable products.
Resinous woods.	
Distillation experiments on northwestern woods in cooperation with the University of Washington.	To secure information regarding the value of northwestern woods for distillation.
Study of methods and processes used in securing rosin by extraction from the wood with chemicals.	To secure data regarding "extraction" methods for securing rosin.

C.—DERIVED PRODUCTS, OR PRODUCTS DERIVED FROM WOOD, BARK, LEAVES, AND THE GROWING TIMBER—Continued.

Naval stores.

Project.	Object.
The naval-stores industry	General review of past and present methods, and recommendations.
Turpentine experiments	To determine the value for turpentining of the following species: Digger pine, western yellow pine, sugar pine, lodgepole pine, Jeffrey pine, and Douglas fir.

Miscellaneous.

Production of ethyl alcohol from wood.	To determine the best conditions for digestion of the wood, such as diameter, time, pressure, and kind and amount of acid, for the production of ethyl alcohol.
Production of tanning materials from woods and barks.	To make experiments with various species from time to time as is deemed advisable to determine their value for the production of tannin.
Investigations into the manufacture of producer gas from wood waste.	To determine the economic value of the manufacture of producer gas from wood waste.
Investigation of the production of volatile oils from leaves and needles of various conifers.	To determine the character and quantity of the volatile oils which can be secured from the leaves, needles, and cones of various conifers.
Comparison of the chemical composition of different woods.	To secure information regarding the chemical composition of different species.

D.—STATISTICAL STUDIES.

Annual production of forest products.

Collection of statistics of forest products in cooperation with the Bureau of the Census.	To show in detail the annual demand upon each kind of wood in the forests of the United States, the fluctuation in years of prosperity and depression, tendencies in wood utilization, changing use of species, and progress in methods to increase the service of wood.

Uses of woods.

Study of the uses of commercial woods.	To secure authentic information and statistics regarding the present uses of the various commercial woods in the United States.
By States	To make an inventory of the annual demand by the various wood-consuming industries in each State for raw material.
By industries	To secure authentic statistics and information regarding the uses of different woods classified by industries.
By species	To secure authentic statistics and information regarding the uses of different woods classified by species.

D.—STATISTICAL STUDIES—Continued.

Lumber prices.

Project.	Object.
Quarterly statistics on lumber prices f. o. b. mills.	To secure periodically wholesale prices of lumber at representative mills in different sections of the country.
Quarterly statistics on lumber prices f. o. b. markets.	To secure periodically wholesale lumber prices at representative markets in different sections of the country.

Miscellaneous.

Collection of statistics on wood preservatives consumed and kind and quantity of timber annually treated in the United States.	To secure data on the kind and quantity of wood preservatives annually consumed, and kind and quantity of material annually treated.
Service tests of eucalyptus and tan-bark oak for cooperage, cross-arms, and insulator pins.	To secure data on the suitability of eucalyptus and tan-bark oak for cooperage, cross-arms, and insulator pins.

Mill scale studies.

[See "Silviculture—Mensuration."]

SILVICULTURE.

A.—FORESTATION.

General.

Reforestation in the East....	To obtain reliable data as to the results of planting in the East with different species as a basis for recommendations to the farmers, and incidentally secure data on growth, volume, and yield of the different species.
Reforestation...............	To prepare manual of nursery work and field planting.

Seed.

Seed-storage experiments....	To determine the best method, temperature, and geographical location for the storage of seed.
Physical characteristics and vitality of forest-tree seeds.	To obtain information as to the germinability, variation in size of the same species but from different sources, and other physical and biological properties of the seeds of coniferous species.
Influence of age and condition of the tree upon seed production in western yellow pine.	To determine the effect of age and condition of seed trees upon the quality of seed produced and resulting generation.

A.—FORESTATION—Continued.

Seed—Continued.

Project.	Object.
Seed cleaning:	
Western yellow pine	To determine the effects of moisture treatment for the removal of wings from western yellow-pine seed.
Seed extraction:	
District 1—	
Eastern white pine, Norway pine, jack pine, western larch.	To determine the best temperature and conditions for extraction of seed.
District 2—	
Lodgepole pine	To determine the relative value of lodgepole-pine seed extracted at various periods during the fall and winter.
Lodgepole pine	To determine the limitation on heat, soaking, etc., desirable in the extraction of lodgepole-pine seed. To determine also the merits of wet and dry cleaning of seed.
Lodgepole pine	To determine the possibility of opening cones of lodgepole pine in direct flame.
Seed testing:	
District 7	To determine the true value of seed collected in the districts.
District 1	To determine the germinating power of samples of seed used in the district; also for the purpose of determining the results of seed-extracting methods.
District 3	To determine the germinating power of all seed samples, concerning which information is desired for the next season's sowing in the district.
Comparative germination in the greenhouse and field.	To determine the comparative germination of seed tested in the greenhouse with that which occurs in actual field operations.
Seed production:	
Western white pine, lodgepole pine, Douglas fir, yellow pine, Engelmann spruce.	To develop a method for determining the amount of seed produced, and determine the periodicity of seed years of different species.
Source of seed:	
District 1	To test the source of seed of western yellow pine, white pine, and Douglas fir.
District 2—	
Douglas fir, yellow pine, lodgepole pine, Engelmann spruce.	To determine the relative value at a middle point of seed and stock from the middle, northern, and southern parts of the range of the species.
District 3	To determine the suitability of seed of western yellow pine from different sources to local conditions.

A—FORESTATION—Continued.

Nursery.

Project.	Object.
Nursery practice:	
District 1	To test different amounts of seed for seed beds, methods of sowing, and depth of covering.
District 2	To determine the final effects of different degrees of watering in the nursery on the stock when it is set out in the field; the effect of shading for different periods on the hardiness of trees when placed in the field; the relative values of manure, leaf compost, and commercial fertilizers; the best time for transplanting and the latitude in time of safety in spring transplanting operations; the most advantageous seasons for seed sowing in the nurseries; the best depth for sowing seed in seed spots and in the nursery; the effect on root development of Engelmann spruce of pruning roots at time of transplanting; the effect on root and crown development of square and oblong spacing in the transplant beds.
District 3	To determine various phases of nursery practice, such as the preparation of the beds, amount of seed of different species to be used per seed bed, watering, and shading; the effect of spacing and the methods of preparation of the ground upon the development of the root system.
Districts 2 and 3	To determine whether it is practicable to grow stock near the planting site without watering and much care.
District 4	To determine to what extent small and weak trees can be eliminated from the nursery by the use of seed graded by weight.
District 5	To carry on experiments to determine the proper amounts of seed of different species which should be sown in nursery beds; to determine the depth of cover, the proper seasons and methods for sowing the seed beds, etc.
District 6	Same as above.

Species, methods, and seasons.

Experimental planting:	
District 1—	
Norway spruce, sugar pine, basswood, white ash, shagbark hickory, western white pine, yellow pine, Douglas fir.	To test the suitability of different species to northern Idaho.
District 2—	
Yellow pine	To determine the best method and season of planting in the following subdistricts: Southeastern, northeastern, and in Kansas sand hills.
Scotch pine	To compare the value of Scotch pine for the north slope of the sand hills, and also for the moister sites in the Pikes Peak region; and to determine its relative merits for Kansas sand-hill planting.
Austrian pine	To determine comparative value of Austrian pine for planting on certain areas of the western yellow-pine type, and its relative merits for Kansas sand-hill ing.

A.—FORESTATION—Continued.

Species, methods, and seasons—Continued.

Project.	Object.
Experimental planting—Con.	
District 2—Continued.	
Lodgepole pine	To determine the best method and season of planting in the northwestern subdistrict.
Eastern white pine, western white pine, Norway spruce, Norway pine, Japanese larch, sugar maple.	To find species which would be adapted to the moister sites in the Pikes Peak region.
Black locust and honey locust.	To determine relative merits for Kansas sand-hill planting on plowed and cultivated ground.
Engelmann spruce	To determine the best method and season of planting in the southeastern and northwestern subdistricts.
Douglas fir	To determine the best method and season of planting in the southeastern, southwestern, and northeastern subdistricts.
Experimental planting and sowing:[1]	
District 3—	
Western yellow pine.	To test experimentally western yellow pine on a comparatively large scale on different Forests and on different sites. Also to reforest by means of the seed-spot method. To determine the best method of planting western yellow pine in pots and with balls.
Douglas fir	To test experimentally Douglas fir on a comparatively large scale on different Forests and on different sites; to reforest by means of the seed-spot method; and to determine the best time of planting.
Jeffrey pine	To test experimentally Jeffrey pine on a comparatively large scale on different Forests and on different sites, and to reforest by means of the seed-spot method.
Alligator juniper	To find a practical way of handling alligator juniper seed and to determine its behavior by the seed-spot method.
Arizona cypress	To determine the suitability of Arizona cypress for reforestation in Arizona.
Black locust, white elm, green ash, desert willow, honey locust, Russian olive, Norway spruce, limber pine.	To determine the suitability of these species to local conditions and the behavior of less common species in artificial planting.
District 5—	
Sugar pine, yellow pine, Douglas fir, white fir, incense cedar.	To determine the best season and the best methods for sowing and planting important species on favorable and unfavorable sites.
Eucalyptus	To determine experimentally the suitability of the less common species to different sites in southern California.
District 6—	
Douglas Fir	To determine the best method and season of direct seeding and planting in lower slope type west of Cascade Mountains; on denuded areas within various types in the Siskiyou Mountains; in humid coast region, Siuslaw Forest; and on denuded areas on slope type of Blue Mountain region.

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[1] More intensive experiments with testing species, sites, methods, and seasons are listed under specific projects which are to serve as a check on this experimental planting on a large scale.

ORESTATION—Continued.

thods, and seasons—Continued.

	Object.
nd nd pine	To determine the best method and season of direct seeding and planting on denuded areas within various types in the Siskiyou Mountains; on denuded areas in slope type of northeast Washington; and on denuded areas on slope type of Blue Mountain region.
Sitka cotch	To determine the best method and season of direct seeding and planting on denuded areas within various types in the Siskiyou Mountains; in humid coast region of Siuslaw Forest; and on denuded areas on slope type of Blue Mountain region.
rdwood	To determine the suitability of eastern hardwood species to bottom lands and slope types west of the Cascades, and to a very small extent east of the Cascades.
ine......	Reforestation studies; experimental seeding and planting in cooperation with New Jersey and South Carolina.
ine......	Same as above.
hortleaf ngleaf	Experimental planting in cooperation with South Carolina to determine the value of the different species for forestation in the southeastern pine belt.
plant- lorida.	To test the suitability of the different species of eucalyptus to different sections of Florida, in cooperation with the State in the Everglades, and in cooperation with the Tampa Board of Trade at Tampa.
ultivation uccess of field plant-	To determine the influence of cultivation in its relation to ground cover on the success of planting operations.
pine, yel- pine, tch pine.	To determine the best stock (seedling or transplant) for field planting.
dding.....	To determine the effect of continuous bedding of sheep on reforestation or natural reproduction.
over.......	To determine the effect of aspen cover on the success of sowing with Engelmann spruce and Douglas fir.
an aspen n Douglas- ting.	To determine the effect of an aspen nurse upon the success of Douglas-fir planting.
of dif- classes of planting: fir, Jef- ine, yellow	To determine the relative value of different classes of stock for field planting.
nting with d stock.	To determine to what extent better results in field planting can be obtained through careful grading of planting stock.
of holding stock over on plant- upon the of field ting.	To determine the advisability of shipping nursery stock to planting areas in the fall to be held there until planting operations commence in the spring.

A.—FORESTATION—Continued.

Sites.

Project.	Object.
Habitat extension:	
Yellow pine	To determine the possibility of growing yellow pine in the piñon-juniper type. To determine the most successful method and season of sowing on ground bearing a fair stand of seed trees and also open sagebrush parks.
Douglas fir	To determine the possibility of using Douglas fir in the lower part of the Engelmann spruce type.
Planting in parks	To determine the possibility of growing trees in the open parks.
Planting on brush-covered, timberless slopes: (*a*) Yellow pine, (*b*) Douglas fir.	To determine whether it is possible to plant southerly steep slopes covered with oak brush and what species should be used.
Comparison of sites for western yellow-pine planting.	To determine the relative value of different sites for yellow-pine planting in District 3.
Reforestation in bear clover areas.	To determine the best method by which the extensive bear clover areas can be gradually transformed into a forest. Study similar to the brush field study in northern California.
Forest extension into the northern brush fields.	To determine the best method and species to plant in the brush fields of northern California so as to gradually extend the forest into the brush fields which once were a forest.
Planting on pumice soil: Western yellow pine in District 6.	To determine the best method and season of planting western yellow pine on light, pumice soils, east of the Cascade Mountains.

Introduction of exotics.

A study of California exotics of possible economic value in this country.	To determine, by a study of the results obtained by the cultivation of various exotics in California, their possible potential range in this country and their probable economic value, together with data as to conditions best adapted to their success.
Maritime pine	To bring together the available information as to the possibilities of introducing maritime pine as a source of naval stores in this country.
Cork oak	To furnish information as to the possibilities of the cork oak in this country as source of the commercial cork.

Special.

Experimental work in basket-willow culture.	To secure improved varieties of basket willows; to develop better cultural methods in growing willows; to secure better methods and devices in handling rods; to encourage growing of willows on land suited to the purpose.
Development of American species of basket willows.	To secure varieties of basket willows better adapted to American conditions than the European species now grown. Hardiness and continued vigorous growth are the principal characteristics desired.

[illegible]—FORESTATION—Continued.

Special—Continued.

[illegible]	Object.
[illegible] Jer-	To test the possibility of growing basket willows on the cheap sandy lands of New Jersey.
[illegible]	To test various means of direct reforestation of the sand dunes on the Siuslaw National Forest.
....	To determine the extent to which erosion of a gully may be checked by willow planting.

B.—INFLUENCES.

[illegible] stream [illegible] Appa-	To determine the effect of forest cover upon stream flow and erosion in the Southern Appalachians.
[illegible] stream	To keep abreast with the literature on the subject.
[illegible]eorologi- [illegible]ks" and	To determine the effect of forest cover upon climate of the area occupied by it, as compared with the open "park."
[illegible] a forest [illegible]ccumula- [illegible] melting [illegible] un-off.	To determine to what extent and in what manner virgin western yellow-pine forests affect the amount of snow reaching the ground, the rate of melting, and the amount of run-off.
[illegible] cover on	To determine the effect of forest cover on run-off and erosion.

C.—MANAGEMENT.

General.

[illegible]ardwoods [illegible]rch, and	Silvicultural study with special reference to growth and volume.
[illegible] central	To obtain a series of regional woodlot studies.
[illegible]dwoods in [illegible]er Valley.	Same as above.
[illegible] own-	To furnish information regarding the handling of timber lands for coal mines.
hardwood [illegible] Southern	To furnish information regarding the management of the different hardwood species in the Southern Appalachians.
[illegible] of the [illegible] lands of [illegible] United	To suggest system of forest management for the southern hardwood bottom species.

C.—MANAGEMENT—Continued.

Methods of cutting.

Project.	Object.
Effect of different methods of cutting in different types upon growth and natural reproduction, District 1.	To ascertain the best silvicultural system of cutting in western white pine, western larch, and western yellow-pine types.
Methods of cutting, District 2:	
Lodgepole pine	To determine the effect of various methods of cutting in mature lodgepole pine stands in inducing reproduction.
Balsam type	To determine a method of cutting which will favor spruce reproduction over balsam in mixed stands of these two species.
Mixed lodgepole pine and Engelmann spruce types.	To determine the method of cutting most likely to favor Engelmann spruce reproduction where it occurs in mixture with lodgepole pine.
Results of different systems of marking, District 3.	To determine the comparative merits of one system of marking over the other.
Effect of seasons and methods of cutting in woodland type, District 3.	To determine the conditions under which the cutting in woodland type results in best regeneration of the stand. Coronado Forest.
Different methods of marking and cutting, District 4:	
Idaho yellow pine	To determine the best method of cutting in the Idaho yellow-pine forest.
Aspen in Utah	To determine the best methods of cutting in aspen stands.
Effect of different methods of cutting upon natural reproduction in Jeffrey pine, sugar pine, mixed type of yellow pine, Douglas fir, and white fir.	To determine the best method of cutting upon natural reproduction and growth of remaining stand.
Methods of cutting in the yellow pine and Douglas fir types, District 6.	To determine the best method of cutting in Douglas fir and yellow pine so as to secure natural reproduction and the best growth of the remaining trees.
Cut-over areas:	
District 1	To determine the conditions under which natural reproduction takes place on areas cut-over under different conditions as a basis for proper silvicultural handling of timber sales.
District 3	To determine rate of growth and loss, rate of regeneration and effect of various factors upon regeneration.
District 5	Same as above.
District 6	To determine the progress of natural reproduction on cut-over areas.
Felling snags and diseased trees.	To determine the actual cost of felling snags and diseased trees, as means of improving condition of the Forest, and to ascertain its bearing upon the establishment of stumpage rates.

C.—MANAGEMENT—Continued.

Brush disposal.

Project.	Object.
Effect of scattering brush after logging upon reproduction, District 3.	To determine the effects of scattering the brush after logging upon reproduction in western yellow-pine stands.
Brush disposal:	
District 4, Idaho yellow pine.	To determine the effect of different methods of brush disposal upon natural reproduction.
District 5	To determine the cost and method of brush disposal. To determine the effect of the removal of brush upon the development of seedlings.
District 6	To determine the effect of brush disposal upon natural reproduction.

Natural reproduction.

The loss of seedlings in the forest during the early stages of development.	To determine the rate of loss of seedlings during the early stages of development and the factors responsible for it.
Reproduction on burns	To determine the progress of reproduction on burned-over areas.
Pole and sapling competition.	To determine the competition between the various species and to observe the replacement of brush on an adjoining south slope.

Thinnings.

District 2:	
Yellow pine	To determine the effect of different degrees of thinning in young yellow-pine stands.
Lodgepole pine	To compare the rate of growth and increment of the trees left after thinning with the increment on new stands obtained by clear cutting. To determine best degrees of thinning in sapling lodgepole-pine stands. To determine the effect of thinning from beneath and thinning from above. To determine the best density in lodgepole sapling stands about 40 years old.
Douglas fir and Engelmann spruce.	To determine effect of different degrees of thinnings in young stands.
District 4:	
Aspen in Utah	To determine the effect of thinning upon the remaining stand.
District 5:	
Douglas fir	To determine the effect of thinning upon the growth of the remaining stand.
Mixed yellow pine, white fir, and incense cedar.	To determine the comparative merits of different degrees and frequency of thinning.

C.—MANAGEMENT—Continued.

Valuation.

Project.	Object.
Valuation of young growth with reference particularly to fire damage.	To determine the value of young growth with particular reference to fire damage.
Valuation of land for agricultural and forest uses.	To determine the value of land for agricultural and forest uses.

D.—MENSURATION.

Volume, growth, and yield:	
District 1—	
Douglas fir, larch...	To secure data on growth, volume, and yield.
Lodgepole pine.....	To secure data on volume, growth, and yield for the less favorable sites on the Deerlodge Forest.
Western white pine, western yellow pine.	To secure growth, volume, and yield data.
District 2—	
Lodgepole pine.....	To construct volume tables which will be of value for more than simple local use. To obtain data for the construction of growth and yield tables.
Western yellow pine.	To construct volume tables which will be of value for more than local use. To obtain data for the construction of growth and yield tables.
Engelmann spruce..	To construct volume tables which will be of value for more than local use.
Growth of western yellow pine stands before and after cutting, District 3.	To determine the growth for stands before and after a selection cutting; also a comparison of the different methods of determining the growth percentage before and after cutting.
Growth, volume, and yield studies, District 4.	
Yellow pine in Idaho...	To secure growth, volume, and yield data as a basis for management of Idaho yellow-pine forests.
Aspen in Utah.........	To secure growth, volume, and yield data of aspen as a basis for the management of aspen stands.
Solid contents of cord wood, District 5.	To ascertain the actual solid contents of cord wood as a basis for estimating timber for pulp wood.
Growth and yield, District 6.	To determine the effect of various conditions of soil density upon the growth of stands in different types.
Fundamental laws of tree growth and comparative rapidity of growth of forest trees, District 7.	To establish the general relationship between the various geometrical characteristics of trees which would enable us to develop quick methods of determining the volume and yield of standing trees and forests and to furnish a basis for comparing different species as to their growth and development.
Mill scale studies, in cooperation with the Branch of Products:	
Douglas fir............	To determine the percentage of clear and common lumber obtained from each grade of Douglas-fir logs in the Columbia River and Puget Sound regions.
Blue gum............	To obtain a mill tally of blue-gum logs.

E.—PROTECTION.

Fire.

Project.	Object.
Methods of fire protection...	To determine the best methods of fire protection.
Progress of the States in forestry and fire protection, and digest of State forest and fire laws:	
Forest fires in the United States and Canada.	To ascertain the causes of forest fires, such as lightning and other climatic causes, extent of damage, together with historical data concerning the large conflagrations.
Recovery of chaparral from fire.	To determine the after effects of fire, and the number of years necessary to reestablish a chaparral cover.
Growing green firebreaks.	To maintain firebreaks by growing mesembryanthemum and similar fire resistant species to the exclusion of chaparral.
Effect of light burning..	To determine the effect of frequent light burnings upon the forest.
Fire damage in mature timber.	To determine the effect of fire upon the growth of mature timber.
Influence of grazing in preventing damage by fire.	To determine the value of grazing (1) in preventing forest fires; (2) in decreasing difficulty of fighting fires.

Grazing.

Effect of grazing on the reproduction of western yellow pine, and plan of management for grazing on yellow-pine lands in District 3.	To determine the amount and severity of damage, and to collect information to use as a basis for proper management of grazing in the yellow-pine type of the Southwest.
Management of grazing in the yellow-pine type in District 4.	To secure authentic information upon which to base definite management of sheep grazing on approximately eight million acres of yellow-pine land in District 4.
Effect of grazing on tree reproduction.	To determine (1) the percentage of seedlings injured by sheep, cattle, and goats for each species of locality; (2) relation of intensity of injury to intensity of grazing, season of grazing and method of handling; (3) the ultimate damage to timber from each of the various kinds of injury; and (4) possibility of eliminating damage by more careful management of grazing.
Effect of grazing on growth and reproduction of aspen in Utah.	To determine the effect of grazing sheep upon the sprouting and ground cover of aspen.
Recuperation of different tree species from injuries by grazing.	To determine definitely the time and character of the injury and the ultimate economical effect of the injury upon tree growth.
Effect of grazing on the reduction of fire risk.	To determine to what extent grazing reduces the fire danger in the forest.
Effect of sheep grazing on yellow-pine reproduction.	To ascertain the effect of sheep grazing, if any, in determining the germination of yellow-pine seed as a basis for the use of sheep grazing as means of artificial and natural reforestation, and as a basis for a grazing policy on cut-over areas.

E.—PROTECTION—Continued.

Diseases.

Project.	Object.
Nursery diseases:	
District 2	To determine the methods of checking fungous diseases of stock in nurseries.
District 3	To determine the best methods of preventing damping-off in seed beds.
Pathological investigations, District 5.	To determine the age of infection of incense cedar by *Polyporus amarus* (dry rot); the age of infection of white fir by *Echinodontium tinctorum;* the relation of decay to fire and lightning wounds; the nature and extent of damage done by needle diseases in yellow pine, Jeffrey pine, white fir, and red fir.
Root mould in transplant beds.	To determine the cause of mould on roots of the transplants of yellow pine.
Effect of mistletoe upon growth and seed production of western yellow pine.	To determine the effect upon the soundness of western yellow pine.
Decadence of white fir on the Crater Forest.	To determine (*a*) underlying cause of the rot, (*b*) size of the trees affected, (*c*) rapidity of the decay, as a basis for a timber-sale policy with regard to white fir.
Decadence of mature western yellow pine.	Work begun 1910. To determine the decadence of western yellow-pine trees left as seed trees on timber-sale areas.

Insects.

Insect attacks on cupped western yellow pine.	To determine the susceptibility of cupped trees to attacks by insects.

Animals.

Methods of combating seed-destroying animals.	To determine the best methods of eliminating seed-eating animals from the sown areas.

Snow.

Damage to reproduction by snow.	To determine the effect of snow upon reproduction.

F.—REGIONAL STUDIES.

Forest conditions in Porto Rico.	To describe the forest resources together with discussion of forest problems.
The forests of Florida [1]	Same as above.
The forests of Mississippi and Alabama.[1]	Same as above.
The forests of North Carolina.[1]	Same as above.

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[1] To be correlated with the wood-using industries of the products.

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